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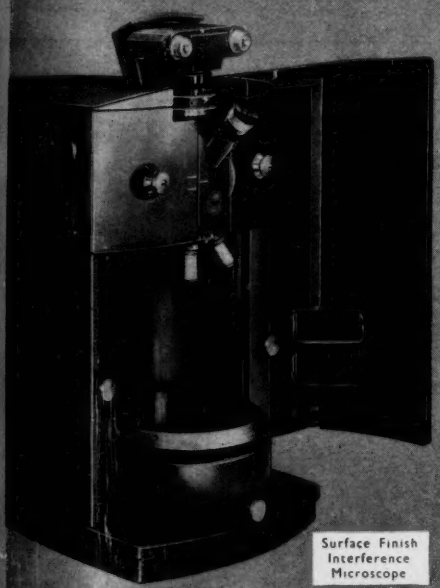

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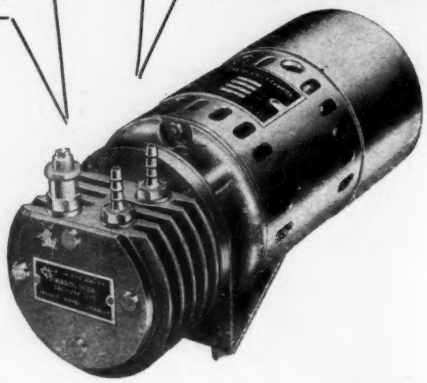

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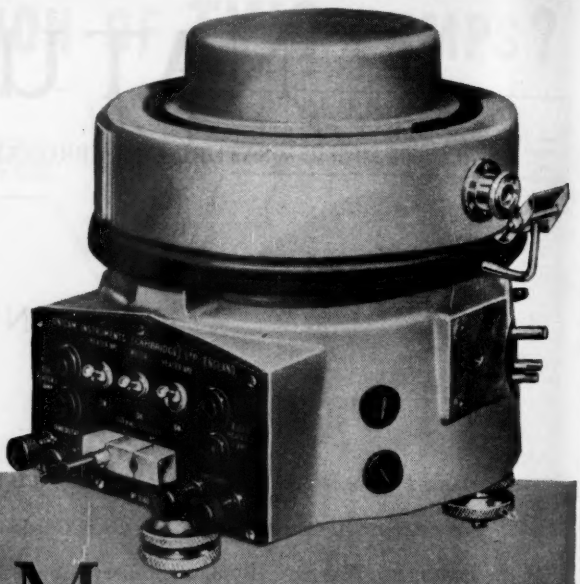

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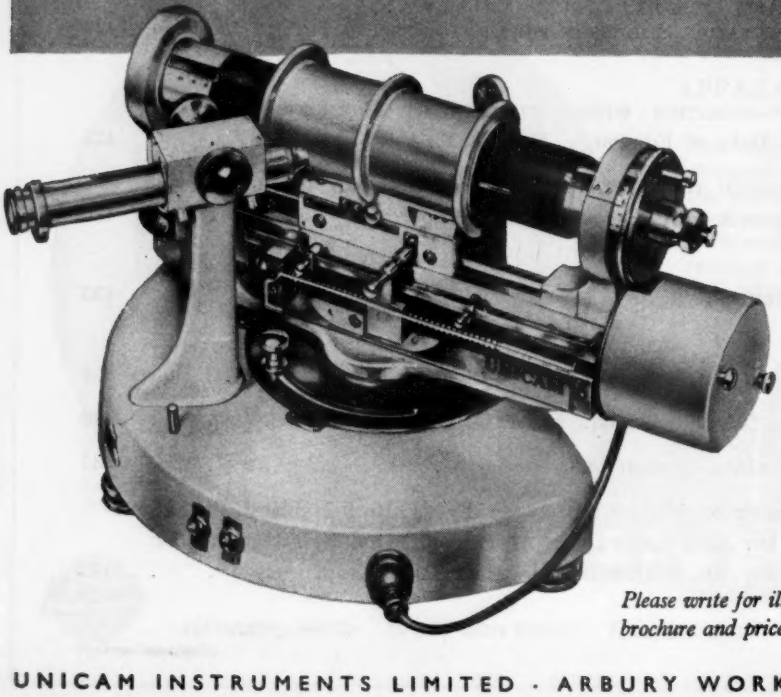

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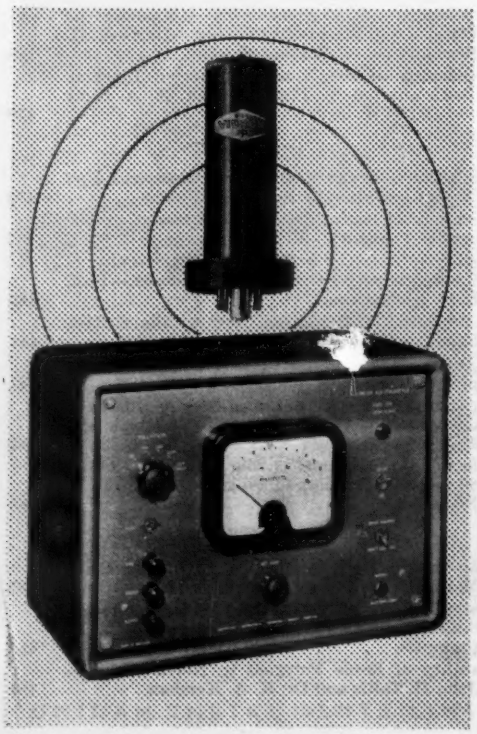

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ART AND SCIENCE OF MANAGEMENT

AT a conference recently organized by the National Institute of Psychology, some ex-Service officers described their attempts to obtain posts in industry and commerce and their subsequent experiences. What surprised them most was the oft-repeated statement that, to be successful in industry, they would first have to unlearn all that they had ever been taught in the Services. Yet, by common consent, the qualities which would enable them to make headway were those that had become part and parcel of their behaviour because of the training they had received in the Forces. The systematic approach to a job, the discarding of the irrelevant and concentration upon the essentials became second nature to men who were steeped in the Service way of life. It is not surprising that these qualities are proving successful in civilian life and that, in the main, officers declared redundant by the Government's changed defence policy are not finding it particularly difficult to obtain suitable openings. These openings, however, are mainly in those companies which already have a proved record of success and are outstanding in their particular fields of activity. They are companies which have systematically developed the right kind of administration pattern to suit their organizations and have selected and developed their executive staff along equally systematic lines. These companies, unfortunately, are but a small proportion of those in British industry as a whole, and, by contrast, give prominence to many present defects and deficiencies.

Since the War the defects and deficiencies have been largely hidden by the boom period which has been called the seller's market. Now that products have to be sold as well as made, industry is becoming more and more aware that its greatest lack is of executive staff with qualities fitted to meet a challenge with which it has not hitherto been confronted. Despite the attention paid to executive development since the War, the large majority of managers in British industry are still men who have succeeded to their posts by their ability to stay in one position longer than other candidates; they have outlived their competitors. Despite the mildness of the present recession, many of them are bewildered by the too rapidly changing conditions, and lack the flexibility to overcome them.

By and large, these managers entered industry in days when the more intelligent and better-educated members of the community chose their careers among the professions. Many of the older managers were recruited from 'black-coated' workers and, as David Lockwood has pointed out*, obtained managerial positions by dint of their proximity to the employer, their superior literacy compared with manual workers, their knowledge of the firm's secrets and its financial affairs, and the tradition which decreed that office workers were more capable of running the business than men drawn from the shop floor. With the relative decline in status and prestige of the clerk, due to the spread of literacy among all sections of the community, as well as the long-overdue recognition of the place of the technologist and technician in industry, it is unlikely that the managers of the future will be drawn from the same sources as hitherto or trained in the same way. They will, in the main, come from the universities and the senior technical colleges, and their training will be consciously organized and much more concentrated.

How they are to be trained is a matter of considerable conjecture, and no fixed rules are likely to be prescribed. The traditional British dislike of 'theory' and strong preference for practical problems, the prejudices of many responsible business leaders who reached their positions 'the hard way' and believe that there can be no other, the fear that young men who study the art and science of management may become over-impressed with their own theoretical knowledge and ignore the wide variations in human behaviour, all tend to preserve the *status quo*.

Of those who believe that management has developed a body of knowledge which can be taught and at a comparatively early age, probably the most able British advocate is Lyndall F. Urwick, chairman of Urwick, Orr and Partners, Ltd. In a privately published pamphlet*, Urwick argues that, in sharp contrast to its regard for the 'practical', the main opposition to the more formal teaching of management in Britain springs from our regard for the amateur. "Being a Director—and 'Director' is as yet the only title carrying social prestige which business and the outside world has recognized—is still, in part, a stronghold of the amateur. Many men are made directors of companies who have neither worked their way up through the ranks of management nor have qualified themselves professionally in other ways, . . . that they have any knowledge of the art and science of management or of the technique of the particular industry or trade with which the Company is concerned, they would be the last people to pretend." Having achieved control of a business through family or social connexions, they look askance at those who suggest that future directors and managers shall have professional qualifications and some knowledge of the art and science of management.

* "The Black-coated Worker" (Allen and Unwin, 1958).

* "Is Management a Profession?" (Urwick, Orr and Partners, Ltd., 29 Hertford Street, London, W.1, 1958).

Despite all the opposition engendered by custom, fear and prejudice, however, Urwick's views are increasingly finding support in British industry and commerce. Instead of learning the skills of management pragmatically over a long period of years, it is becoming clear that the Americans are not wholly wrong, and that there is a body of knowledge which can be taught, as is being done so successfully throughout the United States to-day. It is also becoming recognized that merely to provide short courses for older men is unsatisfactory and inadequate; many of the men who have attended such courses have been unable to profit by them and, as subsequent experience has shown, have returned to their companies with a surface accretion of knowledge which their set ways have made them unable to assimilate. There is a body of knowledge which must be taught when a potential manager is in his formative years. Some can be taught as part of his initial degree courses; much would better wait until he has had a few years doing a management job.

This does not mean that senior managers of the future will be selected for their 'knowledge about' management. In Urwick's own words, "Management is primarily a question of leadership. And leadership, while it can be refined and improved by experience under wise guidance, depends ultimately on the possession of certain qualities of character . . . all responsible people who advocate that management should become a profession are clear that practical experience is the most important element in the development of professional competence. Practical arts cannot be learned from books or lectures. They can only be learned by practice, by knowledge of and acquaintance with the occupation".

What systematic study can do is to make the process of 'learning by experience' more fruitful and more effective. Through books a young student of management can be made more reflective about his experience, can grasp more quickly and clearly what is happening around about him in factory and office. Books and study also help to systematize his experience, to make him more aware of what is lacking and enable him to fill the gaps. By referring the petty details of his early work as a junior to general principles, learning by routine becomes less uninteresting. In this way the well-founded training by apprenticeship will be strengthened when it is made more systematic and supported by theoretical requirements.

Unless the existing methods of training managers by learning on the job is supplemented by a considerable extension of theoretical studies provided by universities and senior technical colleges, British industry is unlikely to meet successfully the challenge before it. The greatest obstacle to progress in British industry is still a body of management which bases its thoughts and actions on traditional practices inherited from its predecessors. Rule-of-thumb must give way to an approach based upon scientific method and, in the present state of British industry, since this is unlikely to be caught, it must be taught.

MARINE ECOLOGY

Marine Ecology

By Prof. Hilary B. Moore. Pp. xi+493. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1958.) 76*s*. net.

THERE has long been need for just such a book as this and which Prof. Hilary Moore is admirably fitted to write. His experience ranges in latitude from Millport by way of Port Erin, Plymouth and Bermuda to Miami and so also covers both shores of the North Atlantic. His research has been equally wide, from his illuminating early studies on intertidal barnacles, dog-whelks and sea urchins, to examination of bottom deposits and of the deep scattering layer. Further, he writes with commendable clarity.

His book is well arranged, leading from description of environmental factors, physical, chemical and biological, to a consideration of habitats, from the abyss to the surface, while the second half of the book is devoted to the organisms which inhabit these environments and are controlled in distribution by these factors. The reader cannot but be impressed, and if he is himself a worker in this general field perhaps a little depressed, by the wealth of information now flooding in from autecologists and synecologists, from physical and chemical oceanographers, from fisheries biologists and statisticians, all of which must in some manner be synthesized. Indeed this is the concluding note of the book, the need for more reviewing and co-ordination of existing information.

Inevitably such a book, even running as this one does to 420 pages of text apart from appendix, references and index, represents the result of selection, and many may feel that more attention should have been paid to matters of particular interest to themselves. Certainly the list of references, though running to twenty-seven pages, is very far from complete. But Prof. Moore would not claim that it was or could be. I feel that more might reasonably have been made of estuarine conditions, including regions of low salinity like the Baltic and Caspian Seas, and especially regret there is no mention of the unique environment and population of mangrove swamps. But it is gratifying that adequate attention is paid to the biological, as distinct from the geographical, aspect of coral reefs.

Among the major impressions which emerge is the realization of how often, in the plankton, on the bottom, on the shore and in the mixed salinities of estuarine waters, it is the organisms themselves which represent the best criteria of environmental conditions. As Prof. Moore points out, the precise nature of the significant environmental factor or complex of such factors often either eludes the observer or else defies adequate measurement.

The wealth of information to be digested in preparing this book doubtless explains why it is a little out of date; there are few references much after 1950. Certainly an author must know when to stop, but it is a pity that more of the recent work on barnacles, where Prof. Moore was so notable a pioneer, has not been included, and there is no mention in the sections dealing with vertical migration of plankton of the highly significant work of Prof. J. E. Harris. But careful reading reveals few errors, although the influence of copper on settlement of oyster larvæ mentioned on p. 95 is surely no longer accepted and there appears to be a misreference to the subject-matter of Table 9–2 on p. 311. Misprints are

commendably few in an extremely well-produced and fully illustrated book which does credit to both author and publisher. The sole drawback is the price, which it is hoped will prevent no institution from adding this book to its library. Marine biologists in general should buy it if they can, but in any event should most certainly read it.

C. M. YONGE

GEOGRAPHICAL CLIMATOLOGY

The Climate of New Zealand

A Geographic Survey. By B. J. Garnier. Pp. 191+12 plates. (London: Edward Arnold (Publishers), Ltd., 1958.) 70*s*. net.

THIS superbly produced and distinctly expensive account of the principal features of the climate of New Zealand is derived in the main from numerous papers in scientific journals. Prof. B. J. Garnier, formerly of Otago and now at Ibadan, asks his readers to regard the volume primarily as an exposition of an important aspect of the country's geography and secondarily as an attempt to show how studies in systematic geography may make their particular contribution to the field of learning.

Like many geographers, he is evidently rather conscious of his subject and the occasional lapses into the jargon of geography are tiresome. "The overall climatic picture of eastern North Island is one in which some diversity is held together in a framework of common distinguishing elements . . . a remarkable quality of the area as a geographic entity is the way this pattern is repeated by other features" (p. 107) will be well understood by students who have been subjected to this sort of thing, but if they want to know about the climate they may still refer with profit to Kidson's ten beautifully concise pages in *The Quarterly Journal of The Royal Meteorological Society* for 1937. Phrases such as "As its name implies, northern New Zealand is the most northerly of the climatic regions" (p. 71); an "influx of influences" (p. 142) are infelicitous. Fortunately, like the southerly rainstorms, these affectations do not last long. There are many agreeable descriptive passages, and in a work on climate the many references to the physical background and the regional characteristics of the vegetation and soil are most welcome; for example, the admirable paragraphs of plant geography on p. 130. The illustration of a summer cold wave is excellent (pp. 118–9).

Beginning with a broad survey of New Zealand's climatic qualities and a discussion of how these have been produced by the combined effect of its position and physiography, the author then defines his climatic regions and in nine chapters discusses their characteristics. The splendidly chosen landscape photographs are a most attractive feature; maps and diagrams abound; synoptic situations and monthly sequences of daily maxima and minima are well displayed; there are useful tables, an extensive bibliography and an index. With its fine assemblage of references, this work is perhaps to be regarded as a regional geography rather than a text on climate; for the present reviewer could find no information about the absolute extremes of temperature, no clear definition of the snow-line, no comment about the marginal qualities of Mt. Egmont, nothing on the climate of Stewart Island; no comment on the astonishing freedom from screen frost at Wellington (p. 170) which, incidentally, makes the averages on p. 169 look a little odd. For the British reader there is no clear indication of how often snow either falls or lies; no map locating the stations; no detail about the frequency of thunderstorms. To say that conditions of permanent frost prevail on the high summits in North Island (p. 126) begs the question. Estimated lapse-rates of temperature in Appendix *A* are not related to upper-air data; and we hear nothing about the extent, if any, of climatic fluctuation in recent times. Rainfall reliability and also evapo-transpiration, a concern of many geographers, receive useful notice. To the regional geographer studying New Zealand as a whole this book, with its abundance of references, extracts, tables and maps, will have many virtues. It is costly, but can be a useful and indeed desirable acquisition to a library.

GORDON MANLEY

TROUBLED WATERS

An Introduction to Fluid Dynamics

By Dr. F. J. Bayley. Pp. viii+215. (London: George Allen and Unwin, Ltd., 1958.) 28*s*. net.

An Introduction to Fluid Dynamics

By Prof. G. Temple. Pp. xi+195. (Oxford: Clarendon Press; London: Oxford University Press, 1958.) 25*s*. net.

Proceedings of the Fifth Midwestern Conference on Fluid Mechanics

Held at the University of Michigan, April 1 and 2, 1957. Edited by Prof. A. M. Kuethe. Pp. viii+388. (Ann Arbor, Michigan: University of Michigan Press, 1957. Published for The Engineering Research Institute, Ann Arbor.) 8 dollars.

THE three volumes under review cater for different sections of the scientific community. Dr. Bayley aims at helping undergraduates in the engineering faculties while Prof. Temple's work is intended primarily for students reading honours mathematics or physics. The proceedings of the Fifth Midwestern Conference on Fluid Mechanics will appeal mainly to the research worker.

The introduction to fluid mechanics provided by Dr. Bayley is unsatisfactory. He has tried to write a simple book covering a wide field. This is extremely difficult to do, especially in two hundred pages, for it demands terse, lucid instruction. Unfortunately in this book the insistence on brevity has led to many vague statements and errors of omission. For example, the paragraph on units will do more to confuse than illuminate the situation. Such a text should surely start with a clear explanation of the three systems of engineering units in current usage and the relations between them. The chapter on fluids at rest contains no mention of floating bodies, and the presentation of the immensely powerful momentum equation is quite inadequate. Moreover, the compressible form of Bernoulli's equation is derived using $p = k\rho^{\gamma}$. This can easily lead students to believe that the equation holds only for this type of flow. Later in the book Dr. Bayley does present the general energy equation both simply and accurately.

Dimensional analysis receives the prominence it deserves and the principle is demonstrated in a number of well-chosen examples. The most successful chapters deal with pipe flow, channel flow and fluid machinery, but the discussion of flow over immersed bodies is poor. The role of viscosity in the production

of lift and drag and the concepts of circulation and an ideal fluid are not clearly explained. It would have been better to have left these tasks to a more specialized text.

The book is attractively presented but some diagrams need alteration; for example, Fig. 9.5 purports to show the pressure distribution around an aerofoil section. There is no scale and in fact the body is an airship hull. There are a few references but no bibliography.

In contrast, the book with the identical title by Prof. Temple is rigorous in treatment and narrow in scope. He says in the preface that "the emphasis in fluid dynamics is no longer on analytical solutions of ingenious problems but on the development of the physical significance of the fundamental principles". Yet his book is not only limited to the theoretical aspect of fluid dynamics but also to the treatment of a perfect fluid deprived of viscosity and compressibility. As an introduction to fluid flow for mathematicians and physicists this is too severe a restriction. Viscosity and compressibility are the two most important properties that a fluid possesses. Unless their importance is realized and used as a guide to useful mathematical solutions, wholly misleading flow patterns based on the ideal fluid concept can result. Prof. Temple could avoid much criticism by re-naming the book "a monograph on the ideal fluid".

After deriving the momentum and energy equations a chapter is devoted to applications of Bernoulli's theorem. The compressible form of this theorem is again derived using "the adiabatic law $p \propto \rho^{\gamma}$", a doubly misleading treatment and the sole mention of compressibility. The existence of a velocity potential is rigorously established, then the method of building potential flows is explained and demonstrated by numerous examples. Among these is the circular cylinder with Thwaites flap. Here the connexion between theory and the behaviour of a real viscous fluid is clearly stated; moreover, the reference to the original work is given. Conformal mapping is used to find the continuous flow around the flat plate, circular arc and usual Joukowski profiles. This is followed by a section on discontinuous flow where the Helmholtz patterns are contrasted with the continuous flow results and the lifts and drags compared. One looks in vain, however, for the vital experimental evidence. The short last chapter is on incompressible slender body theory, the accuracy of which is well illustrated by comparison with the exact potential flow solution for the flow around an ellipsoid.

The whole book is well provided with references and there is a valuable bibliography to which the reader must refer for a more complete and clear picture of fluid dynamics.

Nowadays nearly every conference eventually publishes the papers presented in book form. The Fifth Midwestern Conference on Fluid Mechanics held at the University of Michigan on April 1 and 2, 1957, is no exception. This volume contains twenty-six of the original thirty-two papers.

Since they are nearly all of a specialized nature but on widely different aspects of fluid mechanics this method of presentation seems unwise. Few individuals will relish paying eight dollars for a collection of short reports, only a few of which are of immediate interest to them. Perhaps the book is aimed just at the libraries.

There are, of course, many interesting papers in the eleven sub-sections: stability of flows (3 papers), laminar flow (2), turbulent flow (6), supersonics (2), hypersonics (3), magneto-gasdynamics (1), gas jets in liquids (1), slider bearings (1), free surface (3), marine applications (2) and general (2). Among the authors are Henry Görtler, Lester Lees, Max Munk and S. I. Pai. All the papers are necessarily brief but include an abstract, introduction, brief description and conclusions. All are well provided with references and clearly set out. The figures are first-rate and the whole book beautifully photolithoprinted. The greatest criticism is that no discussion is included. Often at a conference the papers presented provoke important comment and bring to light additional information. All this is lacking, and one is left with the feeling that there must be a better way of distributing conference data to a wider public.

J. L. STOLLERY

MORE PROGRESS IN NUCLEAR ENERGY

Progress in Nuclear Energy
Series 1: Physics and Mathematics, Vol. 2. Edited by D. J. Hughes, J. E. Sanders and J. Horowitz. Pp. vii+375. (London and New York: Pergamon Press, 1958.) 90*s*. net.

FAIRLY soon after the first Geneva Conference on the Peaceful Uses of Atomic Energy there was a spate of books and journals containing, so the publishers said, carefully written reviews of the vast amount of information released at that momentous meeting. In some cases the claim was justified; in others the publications were merely collections of the actual Geneva Papers with precious little editorial comment, and it is to be hoped that this sort of thing will not happen after the recent second Conference.

The first volume in Series 1 (Physics and Mathematics) of "Progress in Nuclear Energy" was, by and large, to be included in the first group and fully justified the publisher's claims. It had some very useful survey articles, particularly, one remembers, on the properties of fissile material.

The second volume in the series has now appeared and is well up to the standard of the first. The articles are again detailed and quite hard going even for the specialist reader. Allen and Henkel open this new collection with an article on the interaction of fast neutrons with thorium, uranium and plutonium. The behaviour of low-energy neutrons with various heavy nuclei is covered by Harvey and Schwartz, and these first two articles continue the useful collection, started in Vol. 1, of the data on cross-sections which are relevant to reactor design.

In reactor physics there is little point in having extensive data on neutron cross-sections unless information is available also on the energy spectra of neutrons in reactors. Precise measurement and calculation of these are difficult, but are being tackled in several laboratories, and the article by Poole, Nelkin and Stone on the "Measurement and Theory of Reactor Spectra" is very opportune.

Until quite recently there have been large discrepancies between the nominal values of the standard neutron sources used in different countries. However, a little international co-operation seems to have improved the position and there is now agreement in most cases to about 1 per cent. The present situation is reviewed by Richmond in an article which gives information also on the procedures used for calibration. Sources used as standards are usually based on

alpha or gamma emitters, although spontaneous fission sources are now being tried.

For studies in neutron physics, sources using particle accelerators are very valuable, particularly as they can be pulsed. The use of pulsed sources in measurements on neutron diffusion is discussed by von Dardel and Sjöstrand in the fifth chapter of this new volume.

The last three chapters are concerned almost exclusively with theoretical aspects. The penultimate chapter, by Hassitt, is on the methods of calculation for heterogeneous reactors, and preceding it is a long discussion of the special problem of resonance escape probability. As the editors state in their preface, the methods of calculation take advantage of developments in computers and this is very evident in the final chapter on "Monte Carlo Methods in Transport Problems".

Altogether this is a nicely balanced collection of valuable articles.

J. WALKER

THE GREEN FLASH

The Green Flash and Other Low Sun Phenomena
By D. J. K. O'Connell, *S.J.* Photographs by C. Treusch, *S.J.* Pp. 192 (24 plates). (Castel Gandolfo: Specola Vaticana, 1958. Distributed by North Holland Publishing Company, Amsterdam; and Interscience Publishers, Inc., New York.) 45*s*.

THE Sun, when close to the horizon before setting, may appear oddly distorted in shape, its upper rim showing traces of green colour while its lower portion is red. As the last segment of the upper rim approaches the horizon, pronounced green coloration may spread from its edges to fill the segment for the few seconds before it vanishes below the horizon. Much more rarely, at the instant when the last segment disappears below the horizon, a green flash may be observed to dart upwards at the point of disappearance. This is not an after-image, the green complementary colour subjectively following the sudden removal of the normal red at sunset, for it may be observed also at sunrise. It occurs when refraction in the atmosphere close to the Earth's surface is abnormally great, that is, when the density decreases rapidly with height. If Rayleigh scattering removes light of shorter wavelength than the green and absorption by water vapour and oxygen is effective in the orange and yellow, then the remaining colours red and green will be so separated by the abnormal refraction that the green will persist for a short period after the red has gone and the transition will be abrupt.

The Vatican Observatory, situated in the Alban Hills at a height of 450 m. with a western horizon at a distance of 80 km. over the Mediterranean, is well situated for a study of these phenomena. The many fine plates in colour and in black-and-white that appear in this volume show how successfully the very difficult tasks of photographing these evanescent effects and of reproducing them here in colour have been achieved. The techniques that were developed in using the Observatory telescopes are fully described, and detailed notes of description and analysis accompany each photograph along with meteorological and other relevant data. There are also some photographs of the green flash at sunrise over land, of the green rim of the setting Moon and of Venus and of experiments with artificial sunsets and layers of discontinuity.

While the author states that the main purpose of the book is "to provide observational material rather than to discuss the various phenomena exhaustively", he provides an interesting account of the history of this subject—it is surprising to learn that the earliest recorded observation of the flash that he deems authentic was made in 1865—a lucid, though brief, account of the theory with an examination of the factors that influence the characteristics of the phenomenon, and a comprehensive bibliography.

JAMES PATON

ECOLOGY AND ECONOMICS OF AGRICULTURAL GEOGRAPHY

American Agriculture
Geography, Resources, Conservation. By Prof. Edward Higbee. Pp. x+399. (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1958.) 64*s*. net.

THIS work is essentially a panoramic description of farming in the United States. The author's obvious interest in soil and water conservation has led him to adopt an ecological, or at least a biogeographical, approach. This gives a refreshing unity to what might otherwise have been a discursive and disjointed book.

Part 1 is a short and elementary but useful introduction to the relations between climate, soils, natural vegetation and 'land capability'. Part 2 is about the dry western half of the United States, where water is the primary limiting factor to agricultural production. The author shows very clearly how the vast irrigation schemes of the Central Valley of California and other western 'valley oases' depend on the control of both soil erosion and floods in the western mountain States. This, in turn, depends on good forest and grazing management in the non-irrigated areas. It affords an excellent example of the value of large-scale ecological integration in agriculture and forestry. Such integration calls for the planning of land and water use on a semi-continental scale. This, in its turn, raises political and social difficulties, which the author mentions; wisely, however, he refrains from offering solutions. Then, after a glimpse at the Pacific North-West, Prof. Higbee crosses the dry Great Plains, where the statistical expectation of drought dominates year-to-year changes in wheat yields and hence the structure of the local agricultural economy.

Part 3 deals with the humid and more complex eastern half of the United States. Here topography, local types of soil, and drainage problems are more important limiting factors than shortage of water, even though sprinkler irrigation is obviously rapidly increasing, particularly in market-gardens and on pastures. The corn (maize), dairy, cotton, and other types-of-farming 'belts' are successively outlined. The emphasis is perhaps more economic and less ecological than it was in Part 2, but these chapters are enhanced by some useful case studies of well-conserved farms.

The book is well illustrated, even though some of the many maps are too small to be readable. There

are perhaps more tables of economic statistics than are really necessary. Further, the book ends somewhat abruptly and unexpectedly in a cranberry bog in Martha's Vineyard, Massachusetts. It lacks a concluding statement.

This is unfortunate. For it is clear to one who has visited nearly all the areas described by the author that his descriptions and bio-geographical analyses are accurate and perceptive. It would have been helpful to know what ecological and economic principles suggested themselves to his mind as a result of this most interesting and informative survey of American agriculture. A. N. Duckham

SCIENTIFIC APPLICATIONS OF SCIENCE

Operational Research in Practice

Report of a NATO Conference. Edited by Max Davies and Michel Verhulst. Pp. ix+201. (London and New York: Pergamon Press, 1958. Published for and on behalf of Advisory Group of Aeronautical Research and Development, North Atlantic Treaty Organization.) 84s. net.

In setting up what was to become the first so-designated Operational Research Section in Fighter Command, Watson-Watt was the first to achieve the most thorough application of science itself. Radar was entirely new, and the momentum of its application carried the scientist into the heart of tactics and strategy. So it was that his formulation of the duties of operational research sections remains valid even until to-day, as Sir Solly Zuckerman emphasizes in his introduction to the report of this North Atlantic Treaty Organization conference.

But how has operational research fared since then? It is still firmly embedded in military practice, despite the shift of emphasis from current operations to future ones, the evaluation of exercises and the development of war games. Here, due to the speed of innovation, there is little scope for hardening into conventional wisdom (to borrow from Prof. Galbraith) in regard to the conduct of military operations, the conventional wisdom of war itself being the accepted framework. But some important applications of operational research were in fields where past procedures, at one time relevant, provided the precedent. Within the Armed Services the civilian scientists were able to make a break-through, perhaps because they were unaffected by conventional wisdom.

Immediately after the Second World War the scope for scientists seemed as wide as human activity itself. The prevailing mood is now more sober, as shown by thoughtful contributions on decision-making and war games, both in civil and military situations, with the need for a theoretical rationale. Logistic and transport problems are shown to have the same basic structure, but let the user beware of an uncritical borrowing of technique, for seemingly slight differences might turn out to be important.

There is, however, one extremely important difference. In civil applications (as quoted) a 1 per cent increase in efficiency (as measured by gross profits) leading to an increase of 5 per cent in distributed profit is an achievement that firms are willing to pay for—whether or not it represents a good national use of scarce man-power. The reaction of a professional soldier is that "in a military context such improvements were seldom ever meaningful or worthwhile". He continues: "The application of operational research principles to operational research was highly desirable, but all too rare". I know of no university where an expert in "tensions in industry" from the sociology department has been invited to report on the tensions within the university. Cecil Gordon

BACTERIAL POPULATION STUDIES IN THE CHEMOSTAT

The Dynamics of Bacterial Populations maintained in the Chemostat.

By Hermann Moser. Pp. iv+136. (Publication No. 614.) (Washington, D.C.: Carnegie Institution of Washington, 1958.) Paper, 1.15 dollars; Cloth, 1.40 dollars.

The study of the mechanisms by which bacterial populations become better fitted to a given environment is of considerable fundamental importance. Of the various methods available for the study of such problems those using a continuous culture apparatus are especially valuable since the cells can be maintained in a state of active growth under defined conditions. In the simplest kind of continuous-culture apparatus the nutrient medium in the culture tube is automatically renewed and immediately a portion of the bacterial suspension is removed, thus maintaining (after a certain time of operation) a steady state. The chemostat superimposes another form of control on the growth, by keeping the concentration of one of the constituents of the growth medium at a sufficiently low level so that the bacterial population grows at a reduced rate which is a direct function of this concentration and is independent of all other nutrient factors.

Although the fundamental theory of growth in the chemostat has been presented by other workers, whose contribution the author generously acknowledges, the genetic theory of populations, it is claimed, has not been presented in a satisfactory way. This task the author has set himself and he proceeds to predict and discuss "the various patterns in which mutants of different kinds may accumulate in a continuously growing population and the ways in which genetic equilibria are attained in such populations". He maintains that "since we are dealing with non-sexual bacteria, the sole factors influencing the frequency of mutants in the population to be considered are the capacity to mutate, and selection". He considers both specific and periodic selection.

On the basis of these assumptions the author proceeds to set up a population model and to examine in considerable mathematical detail the numerous aspects of the problem. The mathematical treatment is the most comprehensive the reviewer has seen and it is recommended to anyone interested in this subject. However, the reviewer feels that it is a pity that the fundamental assumptions of mutation followed by selection were not more rigorously confirmed. It would have provided a better balance if the complementary mechanism of adaptation by non-genetic means had been considered (if only to be rejected), especially since the theory of periodic selection has been challenged for at least one example.

The book is well written and is produced to the usual high standard of the publications of the Carnegie Institution of Washington.

A. C. R. Dean

SCIENTIFIC CO-OPERATION WITHIN THE BRITISH COMMONWEALTH*

By H.R.H. THE DUKE OF EDINBURGH, K.G., K.T., F.R.S.

WE often hear about the invisible ties of friendship and trust which bind together the members of the Commonwealth. We do not hear quite so much about the practical advantages of membership or the amount of quiet unspectacular work which is going on to the mutual benefit of the Commonwealth as a whole. I must admit that it came as quite a surprise to me to discover the amount of useful co-operation in science which is going on within the Commonwealth to-day. I was also delighted to find that this co-operation has been active for quite a long time. It is always the same, and I am sure many have also noticed that there is no better way of finding out about a subject than having to speak about it.

Conferences

One of the first things I discovered was that this address, the subject of which you chose for me, has come at a most appropriate moment because the very first formal step in scientific co-operation was taken exactly fifty years ago. In the year 1909 the Entomological Research Committee for Tropical Africa was formed with headquarters at the British Museum (Natural History), London. The funds came from the African Colonies and the United Kingdom, and it made the first systematic collection and study of insects injurious to men, animals and crops in East and West Africa.

Although this was a very modest venture—the annual budget only amounted to £2,000—yet it was the start of great things.

The venture was discussed at the Imperial Conference of 1911, and in 1913 it became the Imperial Bureau of Entomology, with two main functions: (1) "the identification of all injurious insects sent in by officers attached to departments of Public Health in countries in the Empire"; (2) "to issue a monthly periodical giving summaries of all current literature both British and foreign, dealing with noxious insects, whether agricultural pests or disease carriers". In the same year it published its first journal of abstracts.

Next, the Imperial War Conference of 1918 established the Imperial Bureaux (now the Commonwealth Institute) of Mycology at Kew, and it was the Imperial Agricultural Research Conference of 1927 that set up the first Commonwealth Agricultural Bureaux.

In 1933 the Imperial Committee on Economic Consultation and Co-operation met, and one of its decisions was that there should be a scientific conference every five years which, among other things, was to review the working of the Commonwealth Agricultural Bureaux.

It is therefore plain that this subject of Commonwealth co-operation in science has been given serious consideration for a good many years by many hard-headed and practical people. I also want to make it clear that throughout the story the endeavour has been to benefit the Commonwealth as a whole and not the particular interests of any one country.

Therefore, to resume the story. The first Commonwealth Scientific Conference and First Review Conference of the Commonwealth Agricultural Bureaux was held in London in 1936, and, as a result, two further Bureaux were added. Since then, there have been review conferences in 1946, 1950 and 1955. These concerned themselves mostly with finance and administration, but the last one recommended that the National Institute of Agricultural Engineering should compile and issue abstracts for Commonwealth use.

At the present moment there are three Commonwealth Institutes: the Commonwealth Institute of Entomology at the British Museum (Natural History); the Commonwealth Mycological Institute at Kew (where I opened a new building in 1955); the Commonwealth Institute of Biological Control at the Science Building in Ottawa. There are ten Commonwealth Agricultural Bureaux dealing with the following subjects: animal breeding and genetics at Edinburgh; animal health at Weybridge; animal nutrition at Aberdeen; dairy science and technology at Reading (which I visited in 1954); forestry at Oxford; helminthology at St. Albans; horticulture and plantation crops at East Malling (which I visited in 1957); pastures and field crops at Hurley (which I visited in 1958); plant breeding and genetics at Cambridge; soils at Rothamsted (which I visited in 1954).

Each Institute or Bureau is attached to an institute or laboratory or university department doing active work in that particular science.

A similar but separate undertaking is the Commonwealth Geological Liaison Office, which has been conducting a survey of the mineral resources of the Commonwealth for the past six years. Sixty-five reports have been issued, and the Office has now started to review the position of each of the minerals for the second time.

These organizations are probably the most practical and scientifically useful co-operative undertakings in the Commonwealth to-day. However, that is not the end of the story. At the 1930 Imperial Conference two committees were formed to go into the subject of industrial and fundamental standards. This resulted in the Standards bodies of the Commonwealth countries maintaining regular and systematic consultations, and in 1946 they met in conference in London and again in 1957 in Delhi. There is every reason to believe that they will go on meeting in future because their work has been most rewarding and is proving very valuable to science and industry as well as to Commonwealth trade.

The Second World War inspired the formation of the British Commonwealth Scientific Offices in London and Washington. In them work the Scientific Liaison Officers attached to the High Commissioners' or Ambassadors' staffs. They run themselves and a great many other things besides, and they are without any doubt the most lively force in Commonwealth scientific co-operation at this moment.

I must refer to five more conferences which between them have stimulated a new wave of thought and

* Substance of an Address delivered at the Annual Meeting of the Pakistan Association for the Advancement of Science in Karachi on February 7.

activity on this subject of scientific co-operation. In 1946 the Royal Society in London invited Commonwealth scientists to a conference in which they could speak as individual scientists. Immediately following this conference the Commonwealth Governments organized an official science conference where matters arising out of the Royal Society meetings could be discussed and official action taken. The reports of these two conferences make fascinating reading. First, because of the very obvious harmony and friendly spirit which existed throughout the discussions and, secondly, because of the immense scope of the discussions, which touched every possible aspect of Commonwealth scientific co-operation.

The main topics of the discussions were: agricultural science; medical science; nutrition and special problems of the Commonwealth; mapping and exploration by air; scientific information services in the Commonwealth; interchange of scientists; co-operation with international scientific organizations; standards measurement; interchange of scientific material; land utilization and conservation; mineral resources of the Commonwealth; natural products and chemical industries which might use them; need for fundamental research; co-ordination of scientific work in Africa.

This last problem was considered at a special conference in London in 1949 and in Paris in 1950, and, as a result, the Commission for Technical Co-operation in Africa South of the Sahara, known as C.C.T.A., was formed. The members are: Belgium, the Federation of Rhodesia and Nyasaland, France, Portugal, the Union of South Africa and the United Kingdom. The Commission, among other things, convenes technical conferences, administers the Inter-African bureaux on various subjects, administers the Inter-African Research Fund and has established a number of advisory committees in various fields.

The third important conference was the Royal Society Scientific Information Conference of 1948 which, as its name implies, dealt with the problems of the collection, reproduction, abstraction and distribution of scientific information, particularly within the Commonwealth. This was, in fact, one of the first specialist conferences which had been recommended by the Royal Society meeting of 1946. The Conference suggested the formation of a Standing Committee on Information Services in order to "provide machinery for the interchange and co-ordination of ideas and information" which are emerging from the British Commonwealth as a result of the Conference.

The fourth Conference which is of particular interest was the British Commonwealth Scientific Conference held in Australia in 1952. I say particular interest because it was the first of this series of conferences attended by representatives from Pakistan and Ceylon. As to the business of the Conference I would like to quote a few sentences from the report: "The Conference felt that . . . the day to day contact of the liaison officers provided an effective system of collaboration which necessitated only occasional meetings of the heads of the official scientific organizations" and, later, "In addition to discussing how best to maintain collaboration the Conference dealt with a wide range of questions, including the application of the results of scientific research, the development of information services, the movement of scientists within the Commonwealth, the relations of the constituent organizations with international bodies concerned with science or its application and the provision of technical man-power to assist underdeveloped countries". Again, "It was agreed as particularly important that developments should be watched in the following subjects: industrial microbiology, research in . . . the utilization of low-grade ores, research on the utilization of solar energy by both physical and biological means, infertility of ruminant animals, agricultural engineering". In addition, it discussed the organization of national research bodies.

The Conference was opened by Mr. Menzies, the Prime Minister of Australia, with a most eloquent appeal that the results of scientific research should find their way as quickly as possible into the hands of those who need to have the results.

The fifth Conference was the outcome of the Commonwealth Prime Ministers' meeting in 1957. They recommended an informal meeting of Commonwealth scientists to discuss the use of nuclear energy for civil purposes. The meeting was held during September 15–20, 1958, and every Commonwealth country except Malaya was represented. Not all the delegates were nuclear scientists because the main intention of the Conference was to develop a sense of Commonwealth partnership and inter-reliance in the development and application of nuclear energy. For example, although radioisotopes are produced by nuclear science, they can be used by many other interests—medical, biological, agricultural and industrial.

In the course of their five-day meeting the Commonwealth scientists did a bit of travelling and visited Harwell, the nuclear power station building at Bradwell, Calder Hall and Dounreay. They had one non-scientific interlude when the whole party, numbering about thirty-five delegates, came to lunch with The Queen and myself at Balmoral, and I was delighted to find Dr. Nazir Ahmad and Dr. Ghani among the party.

The latest of this series of conferences was held when the British Commonwealth Scientific Committee met in Canada in August 1958. At this meeting Ghana and Malaya took their places for the first time. The meeting decided to abolish the full-scale scientific conferences and substitute regular meetings of the British Commonwealth Scientific Committee consisting of the heads of the national research organizations of the Commonwealth countries. The Committee has decided to meet again in London in 1960.

The Colombo Plan

All these conferences have given point and direction to scientific co-operation, but no discussion on this subject would be complete without a reference to the Colombo Plan, particularly the technical co-operation scheme. The Plan was the outcome of a meeting of the Commonwealth Foreign Ministers at Colombo in 1950. The main part of the Plan deals, of course, with economic matters; but under the technical co-operation scheme there is a very considerable movement of students and experts in scientific and technological subjects between Commonwealth countries as well as between other south-east Asia countries and the United States. In the past eight years nearly 7,000 trainees and students have received instruction and just over 1,000 experts have been exchanged between the nineteen countries taking part—eleven of them Commonwealth. Of these, only three have not yet received any help and only five have so far been unable to offer any help.

That, I think, is ample proof that this is a real co-operative effort.

Just as an illustration, it may interest you to know that, for example, Pakistan has received help from Australia, New Zealand, Canada and the United Kingdom, and has, in her turn, helped Burma, Japan, Malaya, the Philippines and Ceylon.

There are, of course, many schemes being developed under the Colombo Plan in Pakistan; but I am particularly interested in the Warsak hydro-electric and irrigation scheme because I hope to see how it is getting on in a few days time. It seems to be an excellent example of Commonwealth co-operation, as Canada is providing considerable technical assistance and is footing more than half the bill of 60 million dollars.

The British Association

Although, strictly speaking, the British Association is not primarily concerned with scientific co-operation within the Commonwealth, it has played quite an interesting part in the development of science and scientific institutions in Commonwealth countries. As the representative of the British Association at this meeting, I hope you will forgive me if I say a few words about its contribution. The fact is that as early as 1884 the British Association held its annual meeting for the first time out of the United Kingdom, in Montreal; in 1897 it went to Toronto, in 1905 it went to South Africa, in 1909 it was back in Canada at Winnipeg, and in 1914 it went to Australia. Since then it has been to Toronto again in 1924 and South Africa in 1929. In each case the report makes it quite clear that the personal contacts which were made at those meetings were considered highly valuable, while the suggestions made by the different sections about research projects were almost invariably put into effect. It was not a one-way business either. Visitors to the 1897 Toronto meeting were greatly impressed by the agricultural experimental stations established in Canada and it was recommended that the Council should approach the Home Government with a view to their imitation in Britain.

Modesty forbids me to suggest that any other Association for the Advancement of Science owes anything to the British Association, but they all have one pleasant feature in common. Members of any Association within the Commonwealth are welcome at any Association's meeting and every Association makes a point of inviting a delegation from other Associations to its meetings, and that is why I am here to-day.

Movement of Scientists within the Commonwealth

That, then, is a very general summary of the history and machinery of scientific co-operation within the Commonwealth; but there are, in fact, many other, perhaps more isolated, instances where the fact of the existence of the Commonwealth has affected the course of science.

Perhaps the most convincing example I can choose is the case of Lord Rutherford. Born in New Zealand in 1871, he went to Cambridge as an 1851 Exhibitioner, and from there he went to McGill University in Canada as professor of physics, where he became famous for his brilliant work on radioactivity. In 1907 he moved to Manchester, where he developed his nuclear theory of the atom and accomplished the first artificial transmutation of matter by bombardment with particles. Returning to Cambridge in 1919 as Cavendish professor, he saw his prediction of the existence of the neutron realized by Chadwick.

Two others are of particular interest. Sir Ronald Ross was born in India in 1857 and later trained as a doctor in England. Fired by the vision of Patrick Manson, he returned to India determined to find out the cause of malaria. Within three years he pinned it down to the *Anopheles* mosquito and thus paved the way for the control of one of the worst scourges of mankind.

In a different field Sir Claude Inglis is another example. Trained at Dublin, he went to Sind Irrigation in 1906, and thirteen years later he established the first large-scale hydraulic model station in the world at Poona. In 1945 he returned to England to design and direct the Hydraulics Research Station at Wallingford, and he is now engaged on the Karnafuli scheme for Pakistan.

There is, of course, an excellent example much nearer home, as the University of Lahore recently discovered when they lost Prof. A. Salam to the Imperial College of Science and Technology, London. However, the main thing is that his work on elementary particles will continue to be available to Commonwealth and world science wherever he works in the free world.

This freedom of movement, and the fact that most scientists within the Commonwealth use the same language, are conditions which we should exploit to the greatest extent for the benefit of scientists and through them of science and, ultimately, the people of the whole world.

It has long been recognized that this ability to move about freely within the Commonwealth is a unique advantage, and all the conferences of scientific co-operation have stressed the need for a greater movement of scientists between one country and another.

I was particularly interested to discover that this problem was first tackled as long ago as 1890 by the Commissioners of the Great Exhibition of 1851. In the regulations for their Science Research Scholarships it says: "The Scholarships are 'post-graduate', and are intended to enable selected students of overseas Universities who have already completed a full University course and given evidence of capacity for scientific investigation to devote themselves for two years to research work under conditions most likely to equip them for practical service in the scientific life of the Commonwealth". The Scholarships are tenable anywhere except in the country in which the student has received his scientific education. This scheme was the first of its kind and set the pattern for subsequent awards from other organizations. In 1958 the Commissioners made twenty-five awards.

I am afraid it is not a simple matter to find out exactly how many Commonwealth scientists are in fact studying or working in other Commonwealth countries under some kind of assisted exchange or scholarship scheme. The difficulty arises because the schemes are many and various and are operated by every kind of trust and benefaction.

So far as the United Kingdom is concerned, there are more than 500 schemes in operation designed to help people to study and work in that country, and some 124 to send people out of the United Kingdom. Apart from the 1851 Exhibition Scholarships, the Royal Society and the Nuffield Foundation run a bursaries scheme, and the British Council runs a universities exchange scheme.

The same sort of thing is happening outside the United Kingdom. For example, the National Research Council of Canada offers post-doctorate Fellowships, and, since 1948, some 574 research workers from other Commonwealth countries have worked in Canada, and, at the same time, about 40 Canadians each year are enabled to work in other countries. Under the Colombo Plan, Australia has taken 2,286 students from South-east Asia between 1951 and 1958 at a cost of £3 million.

Up to thirty years ago the Commonwealth and Colonial Empire looked to the United Kingdom as the scientific centre and no one spent much money on scientific research. However, in the past twenty years alone Government expenditure on research throughout the Commonwealth has risen by an estimated factor of fifteen.

Original Scientific Work in Commonwealth Countries

Statistics are well known to be misleading when handled by amateurs; even experts can make them do strange things, and in any event numbers in science give no clue to quality. Let me just remind you of some of the original scientific work carried out in Commonwealth countries other than the United Kingdom. It is an interesting fact that no less than forty-two Nobel Awards have been won by Commonwealth scientists. But, to be more specific, in 1921 Sir Frederick Banting, working with McLeod and Best in Canada, isolated insulin. Sir Macfarlane Burnet in Australia has immensely advanced our knowledge of viruses and their diseases. South African workers have recently developed the tellurometer, which measures base lines for surveying by radar in a fraction of the time needed by conventional methods. Also in South Africa, Sir Arnold Theiler and P. J. du Toit discovered that lack of phosphorus in the soil was the cause of widespread botulism in cattle. Workers in Australia and New Zealand followed this with their discovery of the importance of trace elements in plant and animal health. Edwards in India developed a vaccine against rinderpest. Scientists in Canada have been fighting a long and unremitting battle against black rust in wheat and here in Pakistan research is active in this field as well as in mechanical rice cultivation and in cotton breeding, all of which has an international reputation. The names of Venkata Raman in physics and Ramanujan in mathematics are respected and admired throughout the world.

All this convinces me that the whole Commonwealth would benefit greatly from a larger movement of scientists either as students, research workers, scientific expedition members or as teachers. The important thing, therefore, is to devise practical and simple machinery to encourage this movement to take place.

The present pattern of scientific co-operation within the Commonwealth can be divided into five parts: (1) the regular discussion of general scientific problems and of problems particular to the Commonwealth; (2) the discussion of the problems of the administration of science and research; (3) the regular exchange of scientific information; (4) the movement of scientists; (5) technical help and advice.

(1) and (2) are achieved by regular conferences and contacts between the official research organizations. (3) is achieved by the British Commonwealth Scientific Offices and the Commonwealth Agricultural Bureaux. (4) is achieved by bursaries, scholarships, lectureships and various other schemes of assisted exchange, while the Colombo Plan has encouraged tremendous progress in (4) and (5).

I ought to add at this point that nothing I have said refers to the personal and informal contacts which exist between individual scientists within the Commonwealth. The total of this informal co-operation is probably greater than anything organized through more or less official channels, but of course there are no statistics.

Suggestions to Improve Scientific Co-operation

So far I have only dealt with facts. Now I am going to be rather more rash and put forward some suggestions to increase the amount of co-operation between Commonwealth countries. I will not go so far as to say that these suggestions are possible in practice. I would merely say that they are desirable.

I would like to see the system of the Commonwealth Agricultural Bureaux extended to other sciences and set up in whichever country has the greatest interest in the particular subject. Secondly, I would like to see the system of the British Commonwealth Scientific Offices extended to other Commonwealth countries; this may be a bit premature but, as it is, many Commonwealth countries are doing original research in subjects which are of great interest to others. Thirdly, it would make a wonderful story if countries could pool their resources and plan together the attack on common problems. I say deliberately that it would make a nice story because I do not think scientists or anyone else work that way. It always seems to me that individual laboratories like to attack problems in their own way even though they are quite willing, indeed eager, to discuss the results with anyone who is interested. Therefore, I believe the most we can hope for is a broad agreement about which problems appear to be most important for the time being, followed by a frank exchange of the results of research.

Next I would like to see joint action on scientific problems which affect Commonwealth industry, commerce and trade. Although more than half the research associations in the United Kingdom have Commonwealth members and the flow of technical information is not impeded in any way, except if the industries are in direct competition, I am convinced that wider membership of research associations and more co-operation between research associations in all the Commonwealth countries is both possible and desirable.

However, I am not blind to the complications. Scientists very naturally imagine that anything new which they discover and which seems to them important must be obviously immediately useful to industry. In fact, the most shattering scientific advances may not be of any practical use for many years while some trifling nonsense produced almost by mistake in a laboratory working on, for example, hydraulics may turn out to be vitally valuable to the boot and shoe industry. Furthermore, even if it can be proved quite easily that a particular discovery will revolutionize cotton farming, it does not necessarily follow that cotton farmers will accept and apply the discovery just like that.

For example, I understand that the Laboratories of the Pakistan Council for Industrial Research have, in fact, completed sixteen processes making use of

indigenous materials which are ready for exploitation by industrialists. Some have already been taken up, but I would not be surprised to hear the chairman of that Council say that "you can lead an industrialist to the waters of science but you can't make him drink".

There is only one way to ensure the early application of scientific research. It is essential that industry and all other potential users of scientific production should be as closely associated with the research organization as possible at all times. Industries and farmers must be encouraged to make direct use of research facilities by asking questions, and they must also be made to feel a personal interest in the research activities by being asked to take part in experiments and developments.

The rules of human nature are not really very complex. If somebody offers you advice, the chances are you will tell him to mind his own business; if, on the other hand, he asks you for your advice and help, you are probably rather flattered.

The key to the problem of the application of scientific discovery is the closest collaboration between the research establishments and industry.

Benefits of Commonwealth Scientific Co-operation

So far I have assumed that there is some advantage to be gained from Commonwealth co-operation in science. I have assumed that in the long run the ordinary people of the countries of the Commonwealth will be better off if we make the fullest use of the freedom of movement of scientists and scientific ideas and a common scientific language. However, if this is true, if this business of co-operation is really and practically worth while, there must be some concrete examples which provide conclusive proof. Naturally, I would not have raised this point unless I had that proof.

I think we all agree that where it is possible scientific co-operation should be truly international, and enterprises like the International Geophysical Year, the Organization for European Economic Co-operation, and, on a smaller scale, the Commission for Technical Co-operation in Africa South of the Sahara, and the Colombo Plan show that this can happen. Nevertheless, in spite of the wide differences between the circumstances of the Commonwealth countries, the fact that they have similar institutions often makes it possible to organize co-operation on a Commonwealth scale when it is not possible internationally. For example, international efforts were made for years, without success, to organize the preparation of comprehensive catalogues of cultures of micro-organisms. Preparation of such catalogues within the Commonwealth was organized at a meeting lasting three days.

The Commonwealth operates an "Index of Translations", so that a scientific paper translated anywhere in the Commonwealth is available to any research worker. The Organization for European Economic Co-operation has so far failed in its efforts to organize a similar index.

To add weight to the argument I have chosen two examples which particularly concern Pakistan. Agriculture is, and must remain, the most important industry of Pakistan. For many years the soil will remain its main source of wealth. Anything therefore which advances the art and science of agriculture is vital.

After the First World War investigations were started by meteorologists in England to investigate the behaviour of the layer of air within 100 ft. of the ground about which practically nothing was known. The immediate purpose of this work was military—to study the rate of evaporation from the ground of poisonous gases and the travel of gas and smoke clouds. This work has been continued at Cambridge, and from measurements of the humidity and wind velocity at different heights an electronic computer can calculate the mean water-loss of crops hour by hour. It is then possible to estimate the water consumption of farm crops by physical measurements of the micro-climate. It is a bit early to say what the practical application is going to be; but it shows how scientific research planned for one object in one part of the Commonwealth can produce unexpected techniques and results for other purposes in other places. I hope this matter will be of particular interest to the president of the Pakistan Association for the Advancement of Science, whose work on soil science is well known and who now controls agricultural development in East Pakistan.

The second example concerns a specific investigation. A model investigation is now in progress at the Wallingford Hydraulics Research Station in England to determine the causes of the changes in the bed of the mouth of the Karnafuli River in East Pakistan so that the conditions at the port of Chittagong can be improved and stabilized. This particular piece of work is being done under the Colombo Plan.

In neither case has there been any question of attempting to gain either economic or political advantage. There has been no question of prestige or personal glory. These two cases are typical of hundreds which are in the pipe-lines of Commonwealth co-operation in science, pipe-lines which should be made to carry information and ideas in both directions between all members of the Commonwealth of Nations.

I do not really believe that anyone can seriously doubt that science devoted to fundamental research and the application of natural knowledge to civil and peaceful ends is capable of bestowing the most wonderful benefits upon mankind. In our own time it has brought about a period of almost headlong industrial and therefore economic expansion. I need scarcely emphasize the profound effect which science has had upon medicine and agriculture. (Although the cynic might say that science has simply made it possible for agriculture just to keep pace with the growing demand for food which is a direct result of the effects of improved medical practice.) All the same, there is no use denying that the developments brought about by scientific research have produced a whole host of new problems; problems which can only be alleviated by humane and thoughtful administration; problems which scientists, in company with all other professional groups, must face and overcome as ordinary thinking human beings.

By far the most harrowing problem is the use of science for destructive and warlike purposes. Everyone deplores it; but there is obviously no immediate solution. However, I firmly believe that if we can go on building on this foundation of peaceful co-operation between Commonwealth countries in all spheres of activity, we shall be doing much more than simply helping ourselves; we shall eventually have a structure which will give hope and confidence to all the men and nations of the world and then science at last will be freed for ever from the grim necessity to invent weapons of destruction.

RADIATION AROUND THE EARTH TO A RADIAL DISTANCE OF 107,400 KM.

By Prof. JAMES A. VAN ALLEN and LOUIS A. FRANK

State University of Iowa, Iowa City

Introduction

FOLLOWING the discovery[1-4] of the existence, in a region around the Earth, of a high intensity of corpuscular radiation temporarily trapped in the Earth's magnetic field, it became evident that observations to very great radial distances from the Earth would be desirable in determining the structure and extent of the radiation belt. A proposal[5] for such an undertaking was favourably received by the U.S. National Committee for the International Geophysical Year. Discussions soon thereafter with Drs. William H. Pickering and Eberhardt Rechtin of the Jet Propulsion Laboratory of the California Institute of Technology led to the formulation of a plan for including radiation detectors in one of the payloads of the planned deep-space probes of the U.S. Army Ballistic Missile Agency.

It was agreed that the State University of Iowa group would select, calibrate, and provide detectors and would recommend suitable dynamic ranges for the measurements as indicated by previous satellite observations; that the Jet Propulsion Laboratory would develop and build the necessary circuitry and telemetry and would do the payload engineering; and that the two groups would co-operatively test and calibrate the completed payload and reduce the flight observations. This plan was carried out.

The vehicular part of the programme was already well advanced by the U.S. Army Ballistic Missile Agency and the Jet Propulsion Laboratory (later under the general supervision of the National Aeronautics and Space Administration), and special telemetry receiving stations were being established at Mayaguez in Puerto Rico and at Goldstone Lake, California, by the Jet Propulsion Laboratory.

Radiation Detectors

Of a total payload weight of 13 lb., about 3 lb. was available for the radiation apparatus.

It was decided to use two Geiger–Müller tubes as basic detectors.

(*a*) The first was a standard, halogen-quenched Anton type 302. The regulated high-voltage supply and the scalers were similar to those previously developed at the State University of Iowa for satellite use[6]. Ingenious modifications of the circuits were made by Messrs. W. H. Victor, D. Slaughter and C. Josias of the Jet Propulsion Laboratory to provide for higher counting rates and to permit the mixed transmission on a single, continuous telemetry channel of the counting rate scaled by three different factors: 2^9 (= 512), 2^{13} (= 8,192), and 2^{17} (= 131,072). The experimental value of the dead-time τ of the system was 31·9 μsec. and the apparent counting rate r was well represented by:

$$r = R \exp(-R\tau) \quad (1)$$

where R is the true counting rate. The apparent counting rate r was an increasing function of R up to a value of R of about 33,000 per sec., then a decreasing function of R up to a usable value of R of about 250,000 per sec., with:

$$r_{max.} = (e\tau)^{-1} = 11{,}550 \text{ per sec.} \quad (2)$$

The absolute omnidirectional geometrical factor G_0 of the 302 Geiger–Müller tube was:

$$G_0 = 0{\cdot}75 \text{ cm.}^2 \quad (3)$$

with an uncertainty of ± 20 per cent, at the present date of writing. The uncertainty in the final value of G_0 will be about ± 10 per cent upon completion of a variety of tests on a 'standard' comparison tube. The absolute efficiency of the tube for fast, singly charged, ionizing particles was 0·83 ± 0·05 (also being refined). Hence, if the counter is actuated only by direct penetrations of charged particles, the absolute omnidirectional intensity J_0 (flux through a sphere of 1 cm.² cross-section) is given by:

$$J_0 = 1{\cdot}6\,R, \quad (4)$$

with an absolute uncertainty of ± 20 per cent.

An extensive series of X-ray and γ-ray calibrations of the tube was also made using an integrating Victoreen r.-meter as the standard of exposure-level. Discussion of these calibrations is omitted in this preliminary report. The shielding of this counter had its minimum value of 0·67 gm./cm.² (60 per cent stainless steel and 40 per cent fibre glass and 'Micarta') over a solid angle of about $4\pi/3$ steradians, an 'average' value of 1·0 gm./cm.² over about 80 per cent of 4π steradians and several gm./cm.² over the remaining 20 per cent. It may be noted that the 1·0 gm./cm.² shielding corresponds to the range of 30 MeV. protons or to the extrapolated range of 2·2-MeV. electrons or to the absorption mean free path of 50-keV. X-rays.

(*b*) The second Geiger–Müller tube was one of a batch of tubes specially built for this experiment by the Anton Electronic Laboratories and designated Anton type 213. Its effective omnidirectional geometric factor was about 0·12 of the 302 and it was operated as a counting rate meter with the time-average anode current applied to a d.c. amplifier designed at the Jet Propulsion Laboratory. No in-flight calibration was provided, but special care was

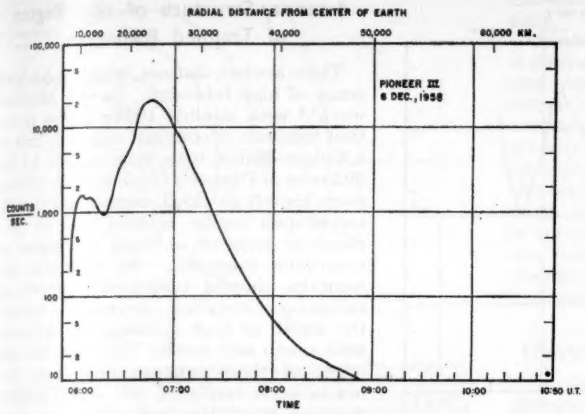

Fig. 1. Semi-log plot of true counting rate R of the 302 Geiger–Müller tube versus time of observation on the out-bound leg of the flight of *Pioneer III*. Radial distance from the centre of the Earth is shown at the top of the figure. The geographical longitude during the period shown was 30° W. at 0600; 0° at 0630; 5° E. at 0700; 4·6° E. at 0730; 2° E. at 0800; 2° W. at 0830. The curve is based on 93 plotted points. Absolute accuracy of individual points is ± 3 per cent from 0556 to 0630; ± 10 per cent from 0630 to 0720; ± 3 per cent from 0720 to 0800 and ± 2 per cent from 0800 to 0850. The lesser absolute accuracy at the higher counting rates is due to inaccuracy of equation (1) of the text

taken in reducing the dependence of the telemetered output upon supply voltages and environmental conditions. The output was a monotonically increasing function of the radiation-level to which the counter was exposed, being linear for low levels and approaching an asymptotic, saturated value for very high levels. Thus, this detector served as a crude radiation-survey device in its own right. More important, its operating characteristics were adjusted so that it served as an 'ambiguity resolver' for the 302, that is, its output was used to decide on which branch of the characteristic curve (cf. equations 1 and 2) of the 302 the latter tube was operating at any instant. This property of the 213 system was an essential one in interpreting the flight observations (see below). The shielding of the 213 tube was nearly identical to that of the 302.

Transmission of Data

All aspects of the radio-telemetry system were handled by the Jet Propulsion Laboratory. A new transmitter, radiating about 150 mW. at 960·05 Mc./sec., was developed and used for the first time. The transmitter was phase modulated by the summed output of three audio-frequency subcarrier oscillators. Channel 1 (centre frequency 400 cycles/sec.) transmitted payload temperature and several other functions. Channel 2 (centre frequency 560 cycles/sec.) transmitted the quasi-d.c. output of the 213 Geiger–Müller tube. Channel 3 (centre frequency 730 cycles/sec.) changed frequency discontinuously (with an effective time constant of 10 sec.) among eight different states corresponding to the output of the composite scaling circuit connected to the 302 Geiger–Müller tube.

The two primary receiving stations were established by the Jet Propulsion Laboratory for the Army probe firings: one near Mayaguez, Puerto Rico, with a 10-ft. dish and one at Goldstone Lake, California, with an 86-ft. dish. Auxiliary receiving stations were located near the launching site at Cape Canaveral, Florida.

Vehicle and Trajectory

The overall vehicular engineering of *Pioneer III* was done jointly by the U.S. Army Ballistic Missile Agency, under the technical direction of Dr. Wernher von Braun and by the Jet Propulsion Laboratory. The first stage was a modified *Jupiter*. The second, third and fourth ('high speed') stages were solid-fuelled Jet Propulsion Laboratory rockets.

The actual flight trajectory was determined by the Jet Propulsion Laboratory by a complex 'best fitting' technique to directional and Doppler-frequency observations from the several receiving stations. The trajectory which has been used in preparing the present article is a preliminary one, the accuracy of which during the re-entry phase is estimated to be of the order of 1,000 km. The outgoing portion of the trajectory is known to an accuracy of ± 100 km. to radial distances of the order of several thousand kilometres. A cumulative deterioration of accuracy occurs thereafter. Recalculation of the 'final' trajectory is still in process. The spatial plots of radiation intensity will be appropriately adjusted in a later article.

In addition, the preliminary trajectory has been converted to eccentric geomagnetic co-ordinates through the courtesy of Dr. Charles Lundquist of the U.S. Army Ballistic Missile Agency.

Log of Flight and Telemetry (*Pioneer III*)

(*a*) *Log of flight.* Launch from Cape Canaveral, Florida, at 0545 U.T., December 6, 1958. (28·5° N., 80·8° W.) Burn-out velocity (space fixed): 10·68 km./sec. Apogee: 108,700 km. radial distance from centre of Earth, geographic latitude 23·74° S., geographic longitude 145·5° E. at 0049 U.T., December 7.

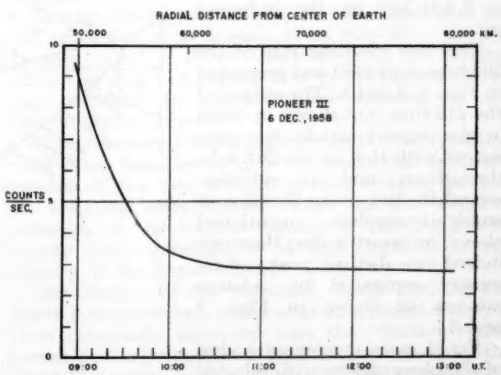

Fig. 2. Linear plot of true counting rate R of the 302 Geiger–Müller tube versus time of observation on the out-bound leg of the flight of *Pioneer III*. The geographical longitude during the period shown was 7° W. at 0900; 17° W. at 1000; 29° W. at 1100; 42° W. at 1200; and 54° W. at 1300. The plot is based on 33 plotted points of ± 4 per cent accuracy each

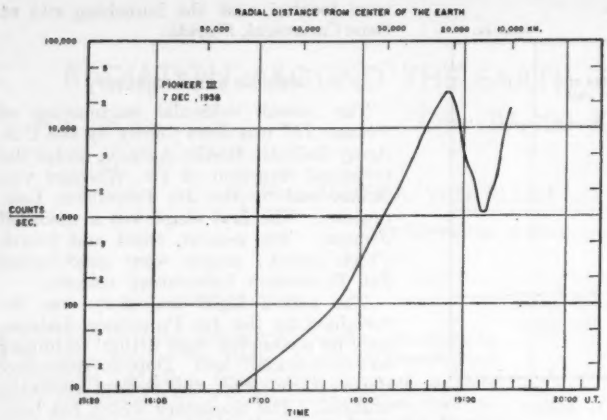

Fig. 3. Semi-log plot of true counting rate R of the 302 Geiger–Müller tube versus time of observation on the in-bound leg of the flight of *Pioneer III*. The geographical longitude during the period shown was 61° W. at 1700; 65° W. at 1800; 64° W. at 1830; 56° W. at 1900; 25° W. at 1930; and 0° at 1936. The curve is based on 48 plotted points with accuracy of each point ± 2 per cent from 1650 to 1820 and no greater than ± 10 per cent thereafter

Extrapolated impact with the Earth: geographic latitude 16·18° N., geographic longitude 20·30° E. at 1943 U.T., December 7.

(*b*) *Log of telemetry.* December 6: 0549–1410 U.T. Puerto Rico—solid telemetry; 1330–2213 U.T. Goldstone Lake—solid telemetry. December 7: 1154–1425 U.T. Puerto Rico—radio-frequency received but signal too weak for readable telemetry; 1425–1520 U.T. Puerto Rico—telemetry intermittently readable; 1520–1930 U.T. Puerto Rico—solid telemetry.

Radiation Observations

Due to excellent telemetry (see previous section), continuous radiation observations were obtained on the out-bound leg of the trajectory to a radial distance from the centre of the Earth of 107,400 km. (nearly to apogee) and from 60,000 km. to 9,400 km. on the in-bound leg.

The true counting rate of the 302 tube is plotted and presented in Figs. 1, 2 and 3. The output of the 213 tube, not shown in detail in the present article, was consistent with that of the 302 tube throughout and in addition served the important function of ambiguity-resolver, mentioned above, in assuring that there are indeed two distinct peaks of intensity separated by relative minima as shown in Figs. 1 and 3.

Fig. 4 gives a schematic view of the observations with selected values of the true counting rate of the 302 Geiger–Müller tube marked on a meridian plane-polar co-ordinate plot of the trajectory.

Intensity-Structure of the Region of Trapped Radiation

There are two distinct, widely separated zones of high intensity. In our previous work[7,8] with satellite 1958ε it was found that contours of constant counting rate of a Geiger–Müller tube very similar to the 302 tube of *Pioneer III*, though somewhat more heavily shielded, suggested a doughnut-shaped region centred on the geomagnetic equator as being the region of maximum intensity. In addition, the contours showed tongue-like regions of radiation extending downward toward the Earth at high geomagnetic latitude, both north and south. The high-latitude edges of these tongues were near the low-latitude edges of the usual auroral zones, a suggestive fact which has been discussed[7,8]. In Fig. 8 of ref. 7 a speculative extension of the contours observed with satellite 1958ε was presented. The diagram given therein was one of two types which we had sketched as plausible extensions of the observed contours. The other one of the two, particularly advocated by C. E. McIlwain of this laboratory, regarded the high-latitude, tongue-like contours as the tips of an outer, banana-shaped region (in meridian cross-section). This view implied a second maximum in intensity as one passes outwards from the Earth in the plane of the geomagnetic equator. The new *Pioneer III* observations show that this second diagram was indeed more nearly true than the one previously published. Our revised and present best picture of the situation is given in Fig. 5. This diagram harmonizes in a single representation our very extensive observations with satellite 1958ε (up to altitudes of 2,200 km.) and the new observations with *Pioneer III*. The latter were the 'one-dimensional' observations along the curved trajectory lines shown in Fig. 5.

The heavy black dots on these lines show specific points through which the contours were

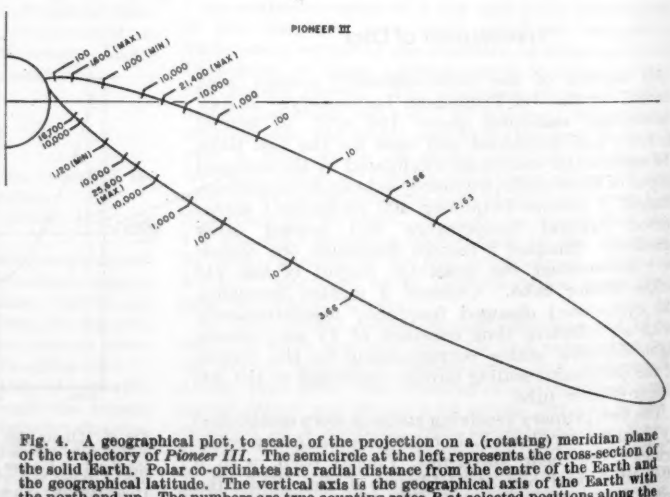

Fig. 4. A geographical plot, to scale, of the projection on a (rotating) meridian plane of the trajectory of *Pioneer III*. The semicircle at the left represents the cross-section of the solid Earth. Polar co-ordinates are radial distance from the centre of the Earth and the geographical latitude. The vertical axis is the geographical axis of the Earth with the north end up. The numbers are true counting rates R at selected positions along the trajectory. The out-bound leg of the trajectory is the upper portion of the curved line

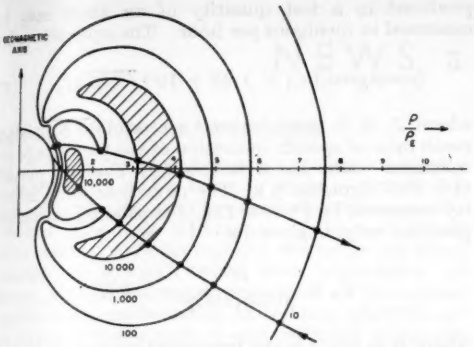

Fig. 5. A plot in a geomagnetic meridian plane of the intensity-structure of the radiation region around the Earth. The numbers associated with the several contours of constant intensity are the true counting rates R of the Geiger–Müller tube in *Pioneer III* or in satellite 1958ε. Within the two cross-hatched areas R exceeds 10,000/sec. See text for further discussion

drawn. Much of the diagram remains conjectural, of course.

The complete intensity-structure of the trapped radiation regions may be more complex than that shown in Fig. 5; but we believe that it cannot be essentially simpler. Inasmuch as the features of the diagram due to 1958ε observations persisted through a two-month period during July–August–September 1958, we regard the outer zone as well as the inner one as a quasi-permanent feature, although the *Pioneer III* observations would not in themselves permit such a conclusion, since they were made within a single two-day period. With detectors of lesser or greater stopping power, the structure of the radiation zones may be found to be different; but results with the diversity of detectors in satellite 1958ε suggest that it will be similar for a wide range of stopping powers.

It now appears that the outer zone is the one more intimately related to usual, high-latitude auroræ.

It will not, of course, be surprising if the level of intensity of trapped radiation and indeed the structure of the entire radiation region are found to be strongly dependent on solar activity, averaged over an appropriate mean trapping time (for example, several weeks or months). In our present view, gross fluctuations on an eleven-year cycle would be expected. Details of the intensity-structure may fluctuate, of course, on a much shorter time scale.

The *Pioneer III* observations give no information on the range spectrum of the trapped radiation. But as previously reported[7,8], the 1958ε observations show that the radiation at high altitudes near the geomagnetic equator is more penetrating than that in high latitudes. This fact together with Fig. 5 encourages one to conjecture that the inner and outer zones may have different physical origins; for example, the outer one due to solar plasma and the inner one due to cosmic ray albedo decay products. Another possibility may be selective radial diffusion of particles in the inhomogeneous geomagnetic field according to their respective magnetic rigidities[9] or according to a combination of the sign of their electrical charge and their magnetic rigidity.

It is obviously of great importance to learn the respective energy spectra of protons and of electrons throughout the trapping region. In the light of the above conjectures, special interest is attached to learning the spectral differences, if any, between the radiation in the inner zone and that in the outer zone.

A satellite in a pole-to-pole orbit of high eccentricity is desirable in order to plot the structure of the radiation region to a good level of satisfaction and to follow its temporal changes. Another attack on the matter can be visualized by using a 'vertical' probe (ideally in the plane of the geomagnetic equator) equipped to measure at each point along its trajectory the angular distribution and energy spectra of electrons and protons separately. Such information is adequate in principle to plot the entire region if one makes full use of the theory of the motion of charged particles in the (approximately known) geomagnetic field.

Effective Radial Extent of the Geomagnetic Field

In the range $27{,}000 \ll \rho \ll 37{,}000$ km., where ρ denotes the radial distance from the centre of the Earth, the counting rate R is accurately represented by an equation of the form:

$$R \sim \exp(-\rho/2300) \qquad (5)$$

Beyond 37,000 km. the counting rate continues to decline smoothly though progressively less rapidly with increasing ρ. Beyond some 64,000 km. ($\rho = 10$ times the radius of the Earth, ρ_E) the rate of decline becomes very much less (Fig. 2).

Although there is nowhere an abrupt cut-off, it appears reasonable, from Fig. 2, to consider the outer limit of the region of trapped radiation to be at $\rho/\rho_E = 10$. At this radial distance the intensity of the trapped radiation, at least as measured with the present equipment, becomes less than the interplanetary cosmic-ray intensity (see the following section). The following quantities are pertinent to a discussion of the significance of this result:

At $\rho/\rho_E = 10$, (*a*) the strength of the idealized dipole field of the Earth is $B = 3{\cdot}1 \times 10^{-4}$ gauss; (*b*) the corresponding magnetic energy density is $B^2/8\pi = 3{\cdot}8 \times 10^{-9}$ ergs/cm.^{3}; (*c*) the maximum magnetic rigidity which a charged particle can have and still be trapped in an idealized dipole field if it is moving in the least favourable trajectory is $pc/ze = 1 \times 10^9$ V. (Störmer cut-off). This magnetic rigidity characterizes a proton of 5×10^8 eV. kinetic energy or an electron of 100×10^6 eV.

It may also be noted that: (*a*) the shielding of our Geiger–Müller tube is such as to stop 30×10^6 eV. protons or $2{\cdot}2 \times 10^6$ eV. electrons; (*b*) the Störmer cut-off at $\rho/\rho_E = 6$ corresponds to the proton energy just sufficient to penetrate the shielding of the Geiger–Müller tube.

Consideration of the observed results in conjunction with these facts leads us to conclude that probably neither of the two straightforward criteria for loss of trapping effectiveness, that is, the Störmer criterion, or the volume density of particle kinetic energy being comparable to the magnetic energy density, is the dominant one.

Disturbance of the idealized dipole field of the Earth is progressively easier at greater radial distance. It is commonly supposed that the effective radial extent of the geomagnetic field is determined by the prevailing interplanetary field. In the circumstances of the flight of *Pioneer III* it appears that the interplanetary field may have been as great as 3×10^{-4} gauss, though perhaps a field weaker by an order of magnitude would suffice.

A more quantitative view of the steady decline of the trapped intensity beyond $\rho/\rho_E \sim 3{\cdot}5$ may indicate that the loss of trapped particles is progressively more probable with greater distance due to intermittent perturbations (from solar gas) the effect of which is, on the average, greater at greater radial distances.

It is of interest and perhaps of significance to note that a dipole line of force through $\rho/\rho_E = 4{\cdot}8$ on the geomagnetic equator reaches the Earth's surface at a geomagnetic latitude of 63°, the approximate lower latitude boundary of the usual zone of maximum auroral activity; and one through $\rho/\rho_E = 10$, at 71·5°, the approximate higher latitude boundary.

Interplanetary Value of Cosmic Ray Intensity

Beyond 10 Earth radii, the counting rate of the 302 declines very gradually and appears to have reached an asymptotic value of 2·25 counts/sec. at the outermost point of the observations, namely, 17 Earth radii. It is not known whether or not there remains a significant contribution from a residuum of geomagnetically trapped radiation or from soft, interplanetary radiations. On the basis of the observed radial dependence of counting rate it is quite likely that the residuum of trapped radiation contributes negligibly at $\rho/\rho_E = 17$.

The Earth's dense atmospheric shell subtends a solid angle of 10^{-2} of a sphere at the position of the apparatus at $\rho/\rho_E = 17$. Hence the Earth is a negligible source of high-energy escaping albedo and is also a negligible scattering and absorbing body for high-energy primary cosmic rays.

The idealized Störmer cut-off at this radius is $0{\cdot}03 \times 10^9$ V. magnetic rigidity, corresponding to kinetic energies of 5×10^8 eV. for protons or 3×10^7 eV. for electrons.

Thus, subject to the above discussion, we find:

$$J_0(\text{interplanetary}) = 3{\cdot}6 \pm 0{\cdot}8 \text{ (cm.}^2\text{/sec.)}^{-1} \quad (6)$$

Almost the entire uncertainty in this preliminary result is due to the uncertainty in the absolute geometrical factor (see section on transmission of data). No previous measurement of J_0 at a point remote from the Earth has been made. The significance of this result will be discussed in a later article.

Fluctuations in Counting Rate Beyond 10 Earth Radii

The counting rate of the 302 tube did not fluctuate beyond statistical expectations during the some 12 hr. of observations at radial distances greater than 10 Earth radii: and in fact, its rate at lesser distances was a remarkably smooth function of time (or of spatial position). This appears to mean either that no 'blobs' of interplanetary plasma were encountered during this observing period or that any such blobs did not contain sufficiently energetic radiation to produce a significant contribution to the counting rate. No critical assessment of the prevailing solar-terrestrial situation has been made as yet. The preliminary Climax report indicates mild to moderate solar activity.

Biological Exposure-Levels

If there is an omnidirectional intensity J_0 of charged particles at a point, then the rate of ionization produced in a test quantity of air there may be measured in roentgens per hour. The equivalence is:

$$\text{(roentgens/hr.)} = 1{\cdot}25 \times 10^{-4}\,\overline{(S/S_m)}J_0 \quad (7)$$

where J_0 is in particles/cm.^{2} sec. and $\overline{(S/S_m)}$ is the mean ratio of specific ionization of the particles to the minimum value for a fast, singly charged particle (1·8 MeV./(gm./cm.^{2})). The omnidirectional intensity measured by *Pioneer III*, if attributed to charged particles only, is given by:

$$J_0 = \frac{R}{(0{\cdot}75)(0{\cdot}83)} = 1{\cdot}6\,R \quad (8)$$

where R in sec.$^{-1}$ is the true counting rate as plotted in Figs. 1, 2, 3, 4 and 5.

For practical use of Figs. 1, 2, 3, 4 and 5, one may combine equations (7) and (8) to give:

$$\text{(roentgens/hr.)} = 2{\cdot}0 \times 10^{-4}\,\overline{(S/S_m)}R \quad (9)$$

For example, the maximum observed exposure-levels in the hearts of the two radiation zones are in the range 5–10 roentgens/hr. if the response of the detector is due only to direct penetrations by electrons. If its response is due only to protons having a rapidly falling spectrum in the tens of MeV. range, as another example, $\overline{(S/S_m)}$ is of the order of 10–20 and the exposure would be in the range of 50–100 roentgens/hr.

It is, of course, understood that these estimates are valid only for the shielding actually used in this experiment (see section on radiation detectors). It is still not known how absorbable the radiation is at various points in space.

Discussion of exposure-levels if the response of the detector is due only to bremsstrahlung from electrons (of energy less than 2·2 MeV.) stopped in the apparatus will be given in a later report.

In addition to the acknowledgments in the body of this article, we should like to mention the many fruitful conversations with Dr. Ernest C. Ray and with Messrs. Carl E. McIlwain and George H. Ludwig of this laboratory.

The engineering of the payload of *Pioneer III* was supervised by Mr. Dan Schneiderman of the Jet Propulsion Laboratory. Support for the State University of Iowa portion of the experimental work and the analysis of observations was provided in part by a sub-contract with the Jet Propulsion Laboratory.

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[2] Van Allen, J. A., Ludwig, G. H., Ray, E. C., and McIlwain, C. E., "Observation of High Intensity Radiation by Satellites 1958 Alpha and Gamma", I.G.Y. Satellite Report Series No. 3: "Some Preliminary Reports of Experiments in Satellites 1958 Alpha and Gamma", pp. 73–92 (U.S. Nat. Acad. Sci., 1958).

[3] I.G.Y. Bull., *Trans. Amer. Geophys. Union*, **39**, 767 (1958).

[4] Van Allen, J. A., Ludwig, G. H., Ray, E. C., and McIlwain, C. E., *Jet Propulsion*, **28**, 588 (1958).

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[6] Ludwig, G. H., *Rev. Sci. Instr.* (in the press).

[7] Van Allen, J. A., McIlwain, C. E., and Ludwig, G. H., *J. Geophys. Res.*, March 1959 (in the press).

[8] Report to Royal Society of London at "Space Research Conference" on November 14, 1958 (paper kindly communicated for us by Prof. S. Chapman).

[9] Cf. Gold, T., *Nature*, [183, 355 (1959)].

NEWS and VIEWS

Prof. C. T. R. Wilson, C.H., F.R.S.

C. T. R. WILSON celebrates his ninetieth birthday on February 14 at his home in Carlops, close to his place of birth, the farmhouse of Crosshouse in the Pentland Hills near Edinburgh. It is now almost half a century since he exposed the air in his cloud chamber to X-rays "with little expectation of success, and in making an expansion of the proper magnitude for condensation on the ions while the air was exposed to the rays, I was delighted to see the cloud chamber filled with little wisps and threads of clouds—the tracks of electrons, ejected by the action of the rays". Here was the instrument which, suitably developed and adapted, was to provide photographs giving an almost complete record of the development of nuclear physics during the succeeding thirty years. The disintegration of nitrogen by alpha-particles was first photographed by Blackett in 1925, and the first example of disintegration produced by neutrons was similarly obtained by Feather in 1932. The power of the Wilson method was greatly extended and its application to cosmic-ray studies facilitated when Blackett devised the automatic control of the chamber by the rays. First evidence for the positron had been discovered by Anderson in 1932, using the method of random expansions; Blackett and Occhialini, using the counter-controlled chamber in the following year, were quickly able to obtain massive support for Anderson's discovery. In 1937 Anderson and Neddermeyer obtained evidence for mesons in cosmic rays from cloud-chamber photographs. While the simpler technique of using fine-grain photographic emulsions for recording nuclear reactions has superseded the cloud chamber, especially in the investigation of the tracks of heavy particles, there are many reactions requiring controlled observation which can be studied only by the Wilson method.

The world-wide recognition that the association of his name with the cloud chamber has brought to 'C. T. R.' has tended to obscure the fact that his investigations of atmospheric electricity and of the electric fields of thunderstorms have provided the basis of our knowledge in this field. Only a year or two ago, he published a paper on the mechanism of the generation of electric charge in thunderclouds in the *Proceedings of the Royal Society*, of which he is senior Fellow. It is perhaps not generally known that the whole of Wilson's scientific work developed out of certain experiences on Ben Nevis—the cloud chamber from his observations in 1894 of glories seen from the edge of the summit precipice overlooking the great corrie, and the thunderstorm work from feeling the effects of sudden changes in the electric field of a thundercloud while standing on the summit of Carn Mor Dearg in 1895. 'C. T. R.' still retains his interest in clouds, and takes every opportunity of flying into them by joining members of the class of meteorology at the University of Edinburgh in flights arranged for them by the Royal Air Force. Some of his colleagues from Sidney Sussex College and former students at Cambridge are to lunch with the Wilson family in the Allan Ramsay Inn at Carlops on Tuesday, February 17.

Rumford Premium of the American Academy of Arts and Sciences: Prof. G. Wald

THE Rumford Premium for 1959 of the American Academy of Arts and Sciences has been awarded to Prof. George Wald, of Harvard University, for his work on the biochemical basis of vision. In addition to the traditional gold and silver medals, this award, established by the Academy 163 years ago, carries a premium of 5,000 dollars to the recipient. The formal presentation will be made at a meeting of the Academy on March 11, 1959. Prof. Wald was born in New York City in 1906. He graduated in New York University in 1927 and was awarded his doctorate by Columbia University in 1932. As a graduate student, he came under the influence of Prof. Selig Hecht, who played an important part in Dr. Wald's subsequent career. During 1932–34 he was a National Research Council Fellow in Berlin, Heidelberg, Zurich and Chicago. He went to Harvard as a tutor in biochemical sciences in 1934 and became professor of biology in 1948. His research has centred on the chemistry of the visual process, with particular reference to the chemical changes which occur in the rods and cones of the eye following excitation by light quanta. Recent work from his laboratory in this field is described in this issue of *Nature*, p. 442.

Royal Society Committee on Scientific Research in Schools

IN order to assist schoolteachers who wish to pursue scientific research the Royal Society established a Committtee on Scientific Research in Schools in March 1957. The following were appointed members: for the Royal Society, Sir Lindor Brown (chairman), Dr. F. P. Bowden, Sir Edward Salisbury; for the Science Masters' Association: Mr. W. Ashhurst, Mr. R. H. Dyball, Mr. M. C. Nokes. Later Dr. C. G. Williams was appointed as an additional member. Dr. Williams is director and general manager of Shell Research, Ltd.; the Committee has been greatly encouraged and assisted by this company, which in 1956 took up this question and is at present supporting research work in nine schools. A statement about the Committee and its aims was circulated to the headmasters and headmistresses of 1,383 schools in the British Isles at the end of 1957. Requests for advice have been received from fifty-seven schoolmasters and mistresses, and twelve research projects are at present being undertaken with the assistance of the Committee, in addition to those previously initiated by Shell Research, Ltd. Twenty-one additional research projects are at present under consideration. The Science Museum Library has agreed to lend periodicals to those carrying out work under the advice of the Committee. Considerable assistance in making literature available has also been given by various university departments and a scheme is being operated by the Royal Institution whereby its library may be used by schoolmasters and mistresses for a small subscription. All research projects with which the Committee is dealing have been scrutinized by Fellows of the Royal Society or by others who have agreed to act as advisers. In a number of cases,

Fellows have lent apparatus from their own departments for particular projects. The response to this scheme has been very encouraging and consideration is now being given to placing under the ægis of the Committee the research projects at present assisted by Shell Research, Ltd. The Committee looks forward both to receiving further requests from schools and to the continued valuable support of Fellows of the Royal Society and others in acting as advisers and assisting in the extension of its activities.

Nuclear Reactors on a Commercial Basis

In reply to a question in the House of Commons on February 5, the Prime Minister stated that the United Kingdom Euratom Agreement was signed on February 4 and the text was published as a White Paper. The prospects for sales of British reactors in the Euratom market, he said, will depend on commercial considerations; but the established achievements of the Calder Hall prototypes and the developments incorporated in the later commercial designs now available for export should give British manufacturers a good prospect of success in Euratom countries. Mr. Macmillan agreed that the ability of the United States to supply fuel for the first year free of charge made it difficult to compete in contracts for power stations, although he believes that Britain is further advanced in this field than the United States are. It is, however, an expanding field and besides the Euratom Agreement Britain has already made separate agreements with individual countries, and this has resulted in an arrangement for a British plant to be erected in Italy.

Fog Dispersal

The Parliamentary Secretary to the Ministry of Transport and Civil Aviation stated in reply to a question in the House of Commons on February 4 that research carried out by the Ministry of Supply indicates that the most promising method of fog dispersal is the thermal one known as F.I.D.O. His Ministry is collaborating with the Ministry of Supply in tests with a new type of F.I.D.O. installed at an R.A.F. aerodrome. This is a high-pressure system with a new type of burner which, it is hoped, will be more economical in operation. The old system was very expensive both to install and to operate. Although F.I.D.O. could provide a clear area, there would still remain the problem of the wall of fog which the aircraft would have to penetrate first. It is considered unlikely that automatic landing equipment would provide a complete solution to the problem.

Electrical Instrument Test Service

The British Scientific Instrument Research Association has established an electrical instrument test service at its laboratories in Chislehurst, Kent. Although originally set up at the request of members of the Association, the service is now available to other firms and organizations. It is operated under the supervision of the National Physical Laboratory and will test and issue certificates for instruments up to 'Precision Grade' accuracy. Calibration of d.c. meters between 1 mV. and 500 V. and between 2 μamp. and 2 amp. can be undertaken immediately. In the near future the latter range is to be extended to 25 amp., and the calibration of a.c. instruments over the ranges 1–500 V. and 10 m.amp.–25 amp. will be undertaken. Charges for the service will be appreciably less than the cost of National Physical Laboratory certification. Further information can be obtained from the Director of Research, British Scientific Instrument Research Association, South Hill, Chislehurst, Kent.

Bird Migration

In addition to its established quarterly journal, *Bird Study*, the British Trust for Ornithology has launched a half-yearly publication entitled *Bird Migration* (1, No. 1; December 1958. iv+40 pp. 2*s*. 6*d*.). This is related to the Trust's recently adopted scheme for co-ordinating the activities of the score of bird observatories which now form a remarkable network around the British coasts, and for ensuring the complete availability and summary publication of the data collected. A grant made for five years by the Nuffield Foundation has enabled the Trust to appoint a whole-time migration research officer, Mr. Kenneth Williamson, who edits the new journal. This first issue includes a series of summary reports from the individual observatories on the autumn migration of 1958, followed by an editorial review of the more notable aspects of the movements as a whole. The season is shown to have been an interesting one in several respects, and this convenient account of it—accompanied by weather maps where necessary—is welcome. The value over a sequence of years should be cumulative.

Plastics Abstracts

Plastics Investigations is publishing a new weekly journal, *Plastics Abstracts*, which aims to give a comprehensive abstracting service covering British patent specifications and periodical articles dealing with the science, technology and applications of plastics. A valuable feature of these abstracts is the promptness with which they are published—normally one week after publication of the original patent specifications, and within two weeks of publication of the periodical articles. The preparation of this journal is based on a complete weekly scrutiny of British patent specifications and the regular examination of about 250 periodicals. Detailed author, patent and subject indexes will be published annually, and subscribers' requests for specific information contained in the current year's abstracts will be answered free of charge. *Plastics Abstracts* is obtainable from the publishers, Plastics Investigations, 23 Canonsfield Road, Welwyn, Hertfordshire. The subscription rates are £25 annually including postage, or £35 by air-mail; single copies can be obtained for 10*s*., or 14*s*. by air-mail.

Drilling a Borehole to the Earth's Mantle

Prof. Hans Pettersson has recently written an article in the *Stockholms-Tidningen* about drilling a deep hole to the Mohorovičić discontinuity between the Earth's mantle and the surface rocks, in which he refers to the article by Dr. T. F. Gaskell in *Nature* of September 13, p. 692, which discussed this project. Prof. Pettersson reminds his readers that the only knowledge of the depth of the base of the Earth's crustal rocks is that obtained from the study of earthquakes. These observations, however, do not allow one to say with certainty what is the rock material which constitutes the Earth's mantle. It is possible that some of the research concerned with the planets and the Moon may give useful clues to what material exists inside the Earth, but there is a strong argument for spending part of the limited amount of money available for research on the more

direct approach of drilling down into the Earth. As Dr. Gaskell pointed out, it is only the cost of drilling to the Mohorovičić discontinuity that is holding the project back: it would be possible from a technical point of view to start to-day. This is especially true of the proposal to drill through the sediments that cover the floor of the deep oceans.

Prof. Pettersson is, of course, one of the world's experts in the deep-sea sediments, but even with his best corers he has managed to penetrate only the top 20 m. of the sea-bed. He points out how important the complete column of deep-ocean sediments will be, because they must surely contain the history of the past geological behaviour of the Earth. Prof. Pettersson does not mention the United States Navy research project which has been set up to look into the economics and desirability of the Mohorovičić and deep-ocean sediments projects which were suggested at the Toronto International Geophysical Meeting in 1957, nor does he say anything about the rumoured Russian attempts to be first in this field.

Regional Museum Council

For many years the Museums Association has endeavoured to obtain some form of assistance from the Government for the smaller museums in Britain. It is well known that in several instances the position is desperate, and valuable material is being lost for want of proper conservation. During the past eighteen months a committee of inquiry in the south-west of England has accumulated facts, and at a meeting at Taunton on January 8 presented a report on the present position of museums in its area together with a series of maps indicating the distribution and size of the collections in the fields of archæology, applied art, fine art, botany, folk-lore, furniture, geology, numismatics and zoology. Dr. W. E. Swinton, president of the Museums Association, was in the chair for this, what may well prove to be a historic, occasion.

After full consideration of the report, it was decided to form a Regional Museum Council. The scope of this Council will include the counties of Bristol, Cornwall, Devon, Dorset, Gloucestershire, Somerset and Wiltshire and the town of Newport in Monmouthshire, while its objects will be to promote co-operation, improve technical facilities and to grant financial assistance to museums and art galleries within the region. The Council will consist of twenty-two members, and it has power to co-opt and make provision for alternate members. Sir John Hobhouse has been appointed chairman and Mr. F. J. Stott vice-chairman of the Council. The outcome of this initial effort on the part of the museums of the south-west of England will be awaited with interest, for if successful it will probably be followed by other regional councils in various parts of the British Isles.

United States Atomic Energy Commission Training Courses

The U.S. Atomic Energy Commission has made grants totalling 2,264,965 dollars to forty-one universities and colleges in the United States for the purchase of laboratory equipment needed to expand their nuclear educational programmes. These grants include funds to seven engineering institutions, namely, Kansas State College and the Universities of Illinois, Maryland, Texas, Washington, West Virginia and Wisconsin, for the purchase of teaching reactors. The seven reactor grants bring to thirty the total number of teaching reactors in operation or to be constructed in American universities with the help of Commission grants.

The U.S. Atomic Energy Commission has also started a new programme of assistance to colleges and universities in the United States for education and training in radioisotope principles and technology. Direct financial assistance is to be given in obtaining demonstration apparatus, student laboratory equipment and training aids needed to offer adequate laboratory course-work in radioisotope technology.

Pyrite Granules and Fossil Micro-organisms

Small spheres, usually less than 50μ across, composed of tightly packed pyrite crystals, are common in sedimentary rocks. They have been noted in rocks of both marine and freshwater origin, from those of the Cambrian to present-day sediments, and have previously usually been considered to be of inorganic origin or to have been associated with the activities of sulphur bacteria. L. G. Lowe has recently shown that spheres of this kind from certain beds of the Scottish Lower Carboniferous oil shale group enclose microfossils of a hitherto unknown group (*Quart. J. Geol. Soc.*, **113**, 429; 1958). The two new monotypic genera, *Pyritosphaera* and *Pyritella*, are both rounded in form and apparently multicellular, the surface of the former being covered with radial spines. The affinities of these genera cannot at present be defined, but they are evidently not bacteria. It is suggested that during their life-time the organisms generated hydrogen sulphide as a by-product of the anaerobic decomposition of sulphur compounds (probably sulphates) and that the gas reacted with iron ions to precipitate iron sulphide on their surfaces. It remains to be seen whether future studies will reveal a range of genera and species capable of being used as stratigraphic or environmental indices, as has been the case with so many other types of microfossils in recent years, but it seems clear that where found *Pyritosphaera* and *Pyritella* demonstrate stagnant conditions at the time the containing sediment was formed.

Morhana Parar

The issue of *Man* of last October contains an interesting article by Dr. Allchin which deals with a number of deep rock shelters in India, called Morhana Parar, which have yielded numerous pigmy tools, and the walls and ceilings of which have been painted. The sites, near the village of Bhainswar, some 42 miles south of Mirzapur on the Great Deccan Road, had been investigated as long ago as 1880 by A. C. Carlleyle, who died before he had been able to deal with his discoveries, and the caves had been forgotten. Some of the 'loot', however, seems to have found its way into several European museums and collections. Now the sites have been rediscovered and studied by Dr. Allchin. The paintings consist of hunting and dancing scenes, chariots and animals. It is to be presumed that the makers of the pigmy tools were the painters.

Disposal of Radioactive Waste

A detailed study of the microbiology and water circulation in the Black Sea by A. E. Kriss (*Priroda*, **6**, 43; 1958) and the water circulation in oceans by V. G. Bogorov and E. M. Kreps (*Priroda*, **9**, 45; 1958) show that the vertical circulation of sea and

ocean waters would not allow the disposal of radioactive waste in their deeper zones (see *Nature*, 182, 563; 1958).

D.S.I.R.: Longer-term Grants for Special Researches

Longer-term grants for special researches will be awarded by the Department of Scientific and Industrial Research in future. These grants—which have normally been limited to a maximum of five years—may now be awarded for an initial period of up to seven years with the possibility of continuing support for a further ten years. When fully established, the support for these researches will be transferred from the Department to a university. The Department is therefore willing to support for longer periods outstanding university investigators embarking on promising researches for which their universities are unable to make adequate provision. The first closing-date for applications is March 1. Further information can be obtained from the Department of Scientific and Industrial Research, 5–11 Regent Street, London, S.W.1.

University News: Birmingham

The following appointments have been announced in the University of Birmingham: G. S. Pittaway to be lecturer in chemical engineering; Dr. W. T. Roberts to be lecturer in industrial metallurgy; Dr. A. L. Haigh to be lecturer in physiology.

Durham

Prof. E. Lederer of the Institut de Biologie Physico-Chimique, 13 Rue Pierre Curie, Paris, will visit King's College in the University of Durham, Newcastle upon Tyne, during March 3–21 and for a further period after Easter.

University College of Rhodesia and Nyasaland

Mr. D. J. Eve has been appointed lecturer in inorganic and physical chemistry.

Announcements

Prof. N. F. Mott, Cavendish professor of experimental physics in the University of Cambridge, has been elected Master of Gonville and Caius College, Cambridge, in succession to Sir James Chadwick, who is retiring.

Mr. W. S. Elliott has been appointed managing director of IBM World Trade Laboratories (Great Britain), Ltd., a new subsidiary of IBM World Trade Laboratories Corporation of New York. At present the Laboratories are at Hursley House, near Winchester in Hampshire, but it is planned to erect a new laboratory in the Southampton area. Research and development are being undertaken in the field of electronic data processing and computing.

A residential working conference on Automatic Programming of Digital Computers will be held in the Department of Mathematics, Brighton Technical College, during April 1–3, under the direction of Dr. A. D. Booth. Further particulars and forms of application can be obtained from the Registrar, Brighton Technical College, Richmond Terrace, Brighton.

The Stress Analysis Group of the Institute of Physics, in collaboration with the Instituut T.N.O., is organizing a conference to be held at the Technische Hogeschool, Delft, during March 31–April 4, at which 55 papers to be distributed beforehand will be discussed. The conference is open to all who are interested: details of the programme and registration forms can be obtained from the Assistant Secretary, Institute of Physics, 47 Belgrave Square, London, S.W.1.

The Parasitology Group of the Institute of Biology is holding its spring meeting at the University of Edinburgh during March 19–22. Twenty-five communications and several laboratory exhibitions have been selected; the proceedings of the meeting will not be published. Those wishing to attend the meeting should register before February 28. Further information on the programme can be obtained from Miss June Mahon, Bedford College, Regent's Park, London, N.W.1.

Two symposia, on "Water and Woodlands" and on "Lysimeters", respectively, organized by the International Association of Scientific Hydrology will be held at Hannoversch–Münden, near Kassel, in Germany, during September 8–13. Intending contributors should submit summaries to the Assistant Secretary, The Royal Society, Burlington House, Piccadilly, London, W.1, from whom further information can be obtained. Completed papers must be submitted by the middle of April.

The eleventh Technical Exhibition of the Oil and Colour Chemists' Association will be held in the New Hall of the Royal Horticultural Society at Greycoat and Elverton Streets, London, S.W.1, during March 17–19. The theme of the Exhibition will be the presentation of technical advances in those industries supplying the paint, varnish, printing ink, linoleum and other allied industries. The technical advances may relate to new products, new knowledge relating to existing products and their uses or, in suitable cases, existing knowledge which is not generally available in the consuming industries. Admission is free for both members and visitors. Further information can be obtained from the general secretary, Mr. R. H. Hamblin, Memorial Hall, Farringdon Street, London, E.C.4.

The Acoustics Group of the Physical Society is sponsoring two symposia dealing with the problem of noise and vibration. The first, at 2.15 p.m. on March 24 in the Physics Department, Imperial College of Science and Technology, London, on "Recent Studies of Noise Problems", will survey recent work on the measurement and effects of noise. It is open to all without formality. The second is a one-day meeting on April 7 in the University of Southampton. Entitled "New Techniques in the Analysis of Noise and Vibration", it will include contributions on aspects of the use of correlation techniques, of digital computers for data processing and analysis, and on general applications of statistical communication theory. It is a joint meeting with the Institute of Physics. Further information can be obtained from D. M. A. Mercer, Physics Department, University of Southampton.

Erratum. In the communication by M. V. Carter entitled "Chemical Destruction of Mature Perithecia of *Mycosphaerella pinodes*", in *Nature* of January 17, p. 162, a line of description was omitted from the headings of columns 3–7 in Table 2. These headings, which refer to concentrations of pentachlorophenol, should read 0·1, 0·2, 0·5, 1·0 and 2·0 per cent, respectively.

LEGUMES IN AFRICAN AGRICULTURE

A TECHNICAL meeting on "Legumes in Agriculture and Human Nutrition" was held recently at Bukavu, Belgian Congo, under the joint auspices of the Food and Agriculture Organization of the United Nations and the Commission for Technical Co-operation in Africa South of the Sahara. Delegates attended from the Belgian Congo, French territories in Africa south of the Sahara, Nigeria, Federation of Rhodesia and Nyasaland, Northern Rhodesia, Southern Rhodesia and Portuguese territories in Africa.

The Agricultural Section at this meeting, under the chairmanship of Mr. A. Angladette, of the Office de la Recherche Scientifique et Technique Outre-Mer, had a very full agenda since attention had to be given to the cultivation of legumes for human food (grain or green vegetable), grazing and fodder production, as well as the improvement of soil fertility through the cultivation of these crops in rotations or as green manures.

Statistics with regard to acreages and production of grain legumes are entirely inadequate; but a general trend may be seen towards increased cultivation of cash crops and the progressive elimination of grain legumes, with the exception of the groundnut where it is grown commercially for export or for oil extraction. Grain legumes may be grown in the garden plot close to the house, in association with other crops and on soils rich in organic matter, or in the 'outfield' in the cropping phase of shifting cultivation.

The most widespread leguminous grain crops at the present time are groundnuts and cowpeas (*Vigna sinensis*), with the haricot bean (*Phaseolus vulgaris*) at the higher altitudes. Interest in *Voandzeia* and the acreage of this plant are decreasing. The greatest need for grain legumes is, however, in the low-lying wet tropics where there are no livestock or grain crops, and the people live on starchy foods such as cassava.

The delegates to the Nutrition and Agricultural Sections of the meeting recognized that some twenty African grain legumes could be regarded as of primary importance from both a nutritional and an agricultural point of view, and that these therefore represented a good basis for future development. The meeting, and particularly the delegates from the Belgian Congo, nevertheless stressed the need for a thorough search in local floras for new legumes for use as food, fodder, shade and cover plants and green manure crops. Any new material which might be found should be the object of study by the plant breeders, who should concern themselves with both quantity and quality (higher protein content and acceptable palatability). Attention should also be given to the production of varieties adapted to methods of cultivation and harvesting involving draught animals or powered machinery.

It would be desirable to facilitate the interchange of seeds of present or new types of plants between the different parts of the region. Seed samples should always be accompanied by adequate data regarding the ecological conditions of the station of origin or place of collection, and also, if possible, by a herbarium specimen for checking purposes. The need to establish herbaria for species and cultivars was also stressed.

The extent of cultivation of legumes for grazing or cut fodder varies considerably as between the different territories. Considerable success was reported in the sod-seeding of *Stylosanthes gracilis* in the existing pastures in the savannah zone. The pigeon pea (*Cajanus cajan*) is grown as spaced hedges in pure Rhodes grass (*Chloris gayana*) pastures in Southern Rhodesia. *Centrosema pubescens* and *Pueraria javanica* are promising for the wetter areas, with *Stizolobium deeringianum* as cut fodder. An important factor limiting the greater use of grazing and fodder legumes is the lack of adequate seed supplies. The meeting, therefore, stressed the need for promoting greater production and better distribution of seeds of legumes adapted to the various regions, supported by a service designed to control quality. Research on seed biology (hard seeds, viability, etc.) is also necessary.

It was agreed that the foremost problem is at present to grow better the legumes already available. There are wide differences between the yields obtained by the average cultivator and those which may be obtained with improved methods of cultivation. Correct and adequate mineral nutrition and an optimal legume/*Rhizobium* relationship are among the primary factors to be considered in this connexion. The policy of fitting the soil to the legume is much more difficult in African peasant agriculture than under more intensive systems of farming. It is also desirable to fit the legume to the soil by the selection, for example, of varieties adapted to either high or low levels of soil fertility. Economic considerations are important in this respect.

On these aspects the meeting recommended that more attention should be paid to fundamental research on legume nutrition and on the factors affecting the development of their associated *Rhizobia*. Workers in Africa south of the Sahara have requested the United Nations Food and Agriculture Organization to publish and keep up to date a world list of scientific institutes pursuing studies on *Rhizobia*, as well as a catalogue of the strains that these institutes have available.

Many examples were quoted of the serious economic losses caused by fungous diseases and insect pests both in the field and in the store. In the latter connexion, it is desirable to evolve cheap methods of grain storage for peasant farmers; for example, oil drums with screw tops into which beans could be placed when quite dry, and in which any beetles or other insects would be smothered. It is desirable that countries should publish a list of the pests and diseases of legumes and evaluate the economic importance of the losses they cause, carry out studies of the biology of the most important ones, develop methods for their prevention and control, and prevent the introduction of pests and diseases from other countries or territories by observing international phytosanitary regulations.

It is obvious that legumes can contribute greatly to the improvement of human and animal nutrition

and to the fertility of the soil in Africa south of the Sahara, as in other parts of the world. Many questions, however, remain unanswered, and the need now is for a well co-ordinated programme of research, dealing with as many aspects as possible but avoiding duplication of effort. The delegates to this meeting repeatedly stressed the need for governments to provide more funds and facilities for this research. They also indicated to the organizations sponsoring this meeting that regional conferences or special study groups could with advantage give attention in due course to the correct utilization and development of the grazing and fodder resources of Africa south of the Sahara, and also to the specific problems of mineral nutrition in relation to legume *Rhizobia*, and the incidence, biology and control of pests and diseases of African legumes.

A report of this meeting will be available shortly in English, French and Spanish.

R. O. Whyte
T. R. G. Moir

GELATINE AND GLUE RESEARCH

THE sixteenth meeting of the Research Panel of the British Gelatine and Glue Research Association was held on December 12, with Mr. S. G. Hudson (Richard Hodgson and Sons, Ltd.) in the chair. Three papers were presented, each by members of the staff of the Association, and were discussed by an audience representative of both the industrial and academic aspects of the work.

The first paper, on "Solubilized Collagen", by Dr. A. Courts and Dr. G. Stainsby, was presented by Dr. Courts, who mentioned briefly the preparation of soluble collagen, especially from the skin and other collagenous tissues of young animals. He then described the modification of the corresponding tissues of adult animals, by cold alkaline pretreatment, to enable the usual solvents for soluble collagen (citric acid and citrate buffers) to extract substantial fractions of the pretreated collagen in the cold. The solutions obtained showed qualitatively similar behaviour to soluble collagen, such as high viscosity in very dilute solution, precipitation in fibrous form on dialysis against distilled water, or on the addition of salt, and conversion to gelatin on warming. Quantitatively, the intrinsic viscosity, while varying to some extent according to raw material and mode of pretreatment, was in agreement with the results of Doty and Nishihara[1] for soluble collagen from calf-skin. Ossein, the demineralized organic component of bone, gave, in a typical experiment, a 30 per cent conversion to solubilized collagen, and there was no reason to regard this as the ultimate limit possible. Sinew and skin were more difficult to convert, but the same general behaviour was observed. The pretreatment processes, if not in detail reversing the process by which collagen is laid down in insoluble form, leave fragments which may have structural significance for the original tissue. The temperature of conversion from the solubilized collagen to gelatin in citrate buffer at *p*H 3·7 was in the region of 30° C., which is lower than that reported for soluble collagen from calf-skin. There is probably only a slight difference in temperature of conversion at neutral *p*H values. The change in optical rotation was measured by Dr. A. Todd, and gave values of specific rotation $[\alpha]_D$ for the soluble collagen and derived gelatin close to those of Doty and Nishihara[1], although confirming the lower conversion temperature of 30° C. noted above.

Mr. A. A. Leach read the second paper, on "The Examination of Gelatine by Passage through Amberlite Resins of the 'I.R.C. 50' (Carboxylic) Type". The paper consisted of a critical examination of the separation of gelatin into two components, by *XE*.97 resin, reported by Mr. G. Russell (Ilford, Ltd.) at the fourteenth meeting of the Research Panel and in a short account in *Nature*[2]. In a typical experiment, a small quantity of gelatine was placed at the top of a resin column previously equilibrated to the required *p*H. Buffer solution at the same *p*H was then passed through the column, fractions collected, and the concentration of protein estimated by the Lowry method, or collected for further analysis. To obtain sufficient of any minor components, large columns of resin were used. It was shown that from *p*H 3 to 5·25 a very small proportion (about 0·3 per cent) of the gelatine used (laboratory sample 127) passed through the column with negligible adsorption, while the remainder was firmly adsorbed as long as the column was not overloaded. Amino-acid analysis of the small eluted fraction gave only a very low content of hydroxyproline, little glycine or proline, and high valine, leucine, *iso*leucine, tyrosine, threonine and aspartic acid compared with the whole gelatine. The analysis is similar to that of Maron[3] for an impurity isolated by adsorption on charcoal.

At higher *p*H, increasing amounts of gelatine 127 are separated in the first peak, while retaining a sharp separation from the remaining adsorbed gelatine. By *p*H 6, 93 per cent of the gelatine was eluted. The percentage eluted could also be increased by overloading a column. Chemical analysis showed that, as soon as several per cent of the gelatine is contained in the first peak, either by overloading or by raising the *p*H, the bulk of the eluted fraction is a substance of gelatin type containing hydroxyproline, with a composition almost identical with the parent gelatin. There was evidence that molecular weight played some part in the separation and a possibility that minor differences in amino-acid composition were also present. No evidence was found suggesting the presence of the 10–20 per cent of a non-gelatin-like component reported by Russell.

The differences between resin batches were shown to be, in the main, accountable in terms of surface area. Two further gelatines (laboratory samples No. 142, *p*I 7·8 and No. 149, *p*I 9·4) of acid-process type showed similar behaviour to gelatin 127 (*p*I 4·95) but the corresponding percentages eluted were found at higher *p*H.

The third paper, "Some Factors influencing the Melting of Gelatin Gels", read by Dr. G. Stainsby, was based on his work with Mr. J. T. Taylor. After reviewing the arbitrary character of melting-point measurement, Dr. Stainsby described the Association's method, which uses as indicator the flow of a drop of carbon tetrachloride down the thin molten layer in contact with the wall of the thin-walled test-tube in which the gel has been set and matured.

The tube is held in a water-bath, the temperature of which is raised ¼ deg. C./min. The method has the advantage of simplicity, thus enabling many variables to be studied. The main contribution of the paper was to show in which conditions the period of maturing of a gel has the most marked effect on its structure as shown by the melting point. If the gelatine solution is rapidly cooled, and then matured at a temperature of 0–10° C., the maturing, after the first hour, has no effect on the melting point, except for the most dilute gels where the setting takes an appreciable time. In contrast, at the higher maturing temperatures (20–25° C.) a marked increase in melting point may be secured by prolonged maturing. These differences in behaviour are presumed to arise from greater powers of re-orientation into stable aggregates at the higher temperature.

Interesting results were obtained by successive maturing at two temperatures. Whereas the melting point characteristic of high-temperature maturing was not changed when this maturing was followed by a further maturing period at a low temperature, the same was not true when the temperatures were reversed. High-temperature maturing could cause a rise in melting point even when it succeeded low-temperature maturing.

The formation of aggregates on cooling gelatin solutions to temperatures above their setting point can be detected by viscosity measurement. In addition, aggregates formed at 25° C. can persist for appreciable times even at 40° C. This work has a bearing on many uses of gelatine and glue, as well as on gel structure.

A. G. WARD

[1] Doty, P., and Nishihara, T., "Recent Advances in Gelatine and Glue Research", edit. by G. Stainsby, 92 (Pergamon Press, 1958).
[2] Russell, G., *Nature*, **181**, 102 (1958).
[3] Maron, N., "Recent Advances in Gelatin and Glue Research", edit. by G. Stainsby, 221 (Pergamon Press, 1958).

NATIONAL RESEARCH COUNCIL OF CANADA

REPORT FOR 1957–58

THE forty-first annual report of the National Research Council of Canada, covering the year 1957–58*, includes the report of the president, Dr. E. W. R. Steacie, the financial statement, and the annual report of Canadian Patents and Development Ltd. Although the latter company shows a slight loss for the year, the prospects of increasing revenue from licences for oil additives, the crash position indicator, the multiple core yarn and the sedimentation device are stressed. During the year the Council provided 3·6 million dollars in support of pure research in the universities by way of 305 scholarships and fellowships, and its 583 scientific research staff (including 142 post-doctorate fellows), 854 technical and 888 general service and administration staff answered 9,500 technical inquiries from Canadian industries. For 1958–59 the Council has recommended that the support given to the universities should be increased to 6 million dollars, but continued growth of government research laboratories is also essential in view of certain limitations on research in industry in Canada.

In 1956, Dr. Steacie points out, Canadian secondary industries, which contribute 22 per cent of the net output and employ 20 per cent of civilian labour, spent about 80 million dollars on research, an increase of 20 per cent on 1955, but 65 per cent of this expenditure was made by a relatively few large companies. Compared with the United States or Great Britain expenditure on research by industry is relatively low.

A major effort is needed to bring about the type of expansion required, and the maintenance of a supply of competent scientists is a reason for ensuring that every encouragement is also given to research in the universities and in Government laboratories.

The Division of Applied Biology has undertaken fundamental work on the effects of irradiation on the development of rancidity in bacon and continued its investigation of railway refrigerator cars. Studies of the structure and development of plant cells and their constituents with the electron microscope were extended, and an improved assay procedure was developed for the toxin-neutralizing substance discovered in culture filtrates of *Penicillium cyanofulvum*, while conversions of up to 50 per cent of sugar to citric acid have been obtained by submerged fermentation of blackstrap molasses. The Atlantic Regional Laboratory completed a systematic survey of the composition of peat in seven large bogs in the Maritime Provinces and its further studies on laminarin sulphate as a blood-anticoagulant have shown that with large doses over a prolonged period this substance tends to be more toxic than heparin. The Prairie Regional Laboratory has developed special columns for the rapid analysis of components of vegetable oils by gas–liquid phase chromatography, and promising yields of lysine and ergot have been obtained by careful study of fermentation conditions, while a new method was developed for the direct separation of starch and gluten from wheat flour.

In the Division of Applied Chemistry, a silver catalyst was used in studying the oxidation of ethylene and propylene, and high-pressure work has included the conversion of gaseous and liquid aldehydes to solids, the measurement of rates of selected reactions as a function of pressure and the determination of changes in the physical properties of gases when highly compressed. The molecular weights of chemical compounds and polymers in the range 40,000–100,000 have been determined and the oxidation-rates of iron and its alloys measured over a range of temperatures by following the gain in weight and by cathodic reduction of the oxidation products. An extensive study was made of the kinetics of polymerization of styrene and α-methylstyrene initiated by sodium naphthalene and much work was done on the fabrication of silver alloys for oxidation catalysts.

In the Division of Pure Chemistry, work continued on the development of suitable methods for deuterating organic compounds, and a study was made of the

* Forty-first Annual Report of the National Research Council of Canada, 1957–58, including the Annual Report of Canadian Patents and Development Limited. Pp. 54. (N.R.C. No. 4783.) (Ottawa: Queen's Printer, 1958.)

instrumental conditions to be met to obtain infra-red spectra that are true physical constants of the absorbing compounds. Comprehensive measurements are being made of the specific heat of elements of the diamond structure (diamond, silicon and germanium) in the temperature region 2°–300° K. and a Calvet type microcalorimeter is being constructed. The study of the influence of surface forces on the rates of flow of fluids through capillary systems and of the nature of the forces responsible for the sorption of acids and dyes by textile fibres continued.

In its work on the control of noise, the Division of Applied Physics gave some attention to communication in high ambient noise. The process of establishing Canada's standards in electricity and mechanics is approaching completion. Temperature measurements of very high precision are being made to determine some of the limits of accuracy of the International Temperature Scale and to investigate the possibility of replacing later some of its fixed points. Besides work on the redefinition of the international metre, comprehensive studies on aerial triangulation continued, and detailed studies by the photometry laboratory should lead to an improved primary standard of light.

The Division of Pure Physics reports important advances in studies of the interaction of energetic μ-mesons with carbon nuclei; an extensive experimental study of the transition metals was completed; a new theory of the processes of strain hardening has been developed and a new type of phase transition in solids discovered. The structures of propiolic aldehyde and vinyl cyanide were determined in the microwave laboratory. A new approach to the general theory of relativity has been formulated on the basis of a new principle of observation.

In the Division of Mechanical Engineering, a very thorough investigation was made into the status of production, research and development in non-metallic structural materials in Canada, and work was almost completed on several projects for the St. Lawrence Seaway. Besides problems related to the design and powering of ships, substantial work was undertaken on the examination of aircraft turbo-jet and turbo-propeller engines under simulated icing conditions. Work is in progress on the aerodynamic problems of aircraft capable of vertical take-off and short take-off, and on techniques for measuring the dynamic characteristics of aircraft at high speeds. An emergency radio beacon, simple and light in weight, was developed by the Radio and Engineering Division to survive aeroplane crashes, as well as a device using transistors to switch off electric buoy lights during daylight and a photoelectric control which puts the diesel-electric plant at Pelee Passage lighthouse into operation between dusk and dawn. Microwave equipment is being developed to provide accurate fixes of position for hydrographic vessels, and a method was devised for measuring the gradient of voltage across each unit of a high-voltage suspension insulator string. Daily observations of 10-cm. radio-emission from the Sun were continued at the Radio Astronomy Observatory, and completion of the Springhill Meteor Observatory provided a new headquarters for meteor research, while auroral radar units are being operated continuously at four stations.

ACTION OF LIGHT ON VISUAL PIGMENTS

from

THE BIOLOGICAL LABORATORIES, HARVARD UNIVERSITY

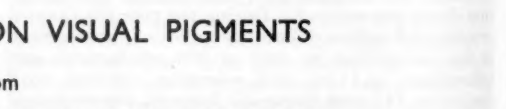
Vertebrate Lumi- and Meta-rhodopsins

By Dr. RUTH HUBBARD, PAUL K. BROWN and Dr. ALLEN KROPF*

RHODOPSIN, the red photosensitive pigment of rod vision, consists of the colourless protein, rod opsin or scotopsin, carrying neo-*b* (11-*cis*) retinene as chromophore. In the light, rhodopsin bleaches through orange-red intermediates (lumi- and meta-rhodopsin) to the yellow mixture of all-*trans* retinene and opsin.

The bleaching of rhodopsin proceeds in three steps, the first photochemical, followed by two thermal reactions[1]. Light initiates this reaction sequence by isomerizing the *cis* chromophore of rhodopsin to the all-*trans* configuration, so converting rhodopsin to the all-*trans* chromoprotein, lumirhodopsin[2,3]. Below about −40° C. lumirhodopsin is stable[1]; above this temperature it changes in light or darkness to a second all-*trans* chromoprotein, metarhodopsin[1–3]. Below about − 15° to − 20° C. metarhodopsin is stable[1]. At higher temperatures, all known vertebrate metarhodopsins hydrolyse spontaneously in the dark to all-*trans* retinene and opsin. Only this last reaction entails a major change in colour, that is, bleaching. Visual excitation, however, is so rapid as to leave time only for the first or second step, and must therefore precede bleaching[1,2].

Light, having isomerized the *cis* chromophore of rhodopsin to the all-*trans* configuration (lumi- or meta-rhodopsin), can go on to isomerize this to *cis* configurations, thus forming rhodopsin (11-*cis*), and isorhodopsin (9-*cis*). In conditions under which lumi- or meta-rhodopsin are stable, prolonged irradiation therefore always yields stereoisomeric mixtures of lumi- or meta-rhodopsin with photoregenerated rhodopsin and isorhodopsin. This situation can be summarized as follows[2,3]:



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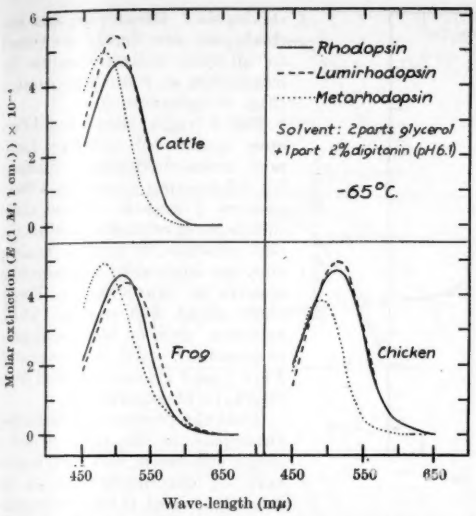

Fig. 1. Absorption spectra of rhodopsins, lumirhodopsins and metarhodopsins from cattle, bullfrog (*R. catesbiana*) and chicken. Rhodopsin spectra were measured directly; lumi- and meta-rhodopsin spectra obtained as described in the text. All are averages of 2–4 experiments. The extinction coefficients of the rhodopsins at − 65° C. were derived from the extinction coefficients at room temperature, by cooling solutions of known extinction to − 65° C., and correcting for volume shrinkage of the solvent (4·5 per cent). The extinction coefficients of cattle and frog rhodopsin in glycerol–digitonin at room temperature ($\varepsilon_{max.}$ = 42,000) were measured by methods previously described (ref. 7), and assumed to be the same for chicken rhodopsin. The extinction coefficients of the lumi- and meta-rhodopsins were obtained by measuring the extinction of rhodopsin which disappeared when a given extinction of lumi- or meta-rhodopsin was formed (cf. Fig. 3). Cattle rhodopsin was prepared from isolated rod outer limbs (ref. 10); bullfrog rhodopsin from alum-hardened retinas (ref. 14). Chicken rhodopsin was obtained by incubating a preparation of mixed rod and cone opsins (ref. 15) with excess neo-*b* retinene. This yields a mixture of chicken rhodopsin and iodopsin. The iodopsin, which is labile in the presence of hydroxylamine (ref. 15), is then destroyed by incubating the mixture ½ hr. at room temperature with 0·3 *M* hydroxylamine

We have recently examined lumi- and meta-rhodopsins from five species of vertebrates, and two cephalopods. These are described in the present and following communications. However, we must first clarify our terminology.

We use the terms *lumirhodopsin* and *metarhodopsin* to designate the two all-*trans* chromoproteins resulting from the photoisomerization of rhodopsin. As will be seen, the spectroscopic properties of these compounds—wave-length of maximum absorption ($\lambda_{max.}$) and molar extinction coefficient at $\lambda_{max.}$ ($\varepsilon_{max.}$)—differ somewhat from one species to another. Rhodopsins also exhibit species variations in these properties[4,5]; yet we designate as a *rhodopsin* any visual pigment composed of neo-*b* retinene and a rod opsin. The fact is that rod opsins, like most proteins, differ somewhat from one species to another, and this leads to species differences in the absorption properties of the rhodopsins, and lumi- and meta-rhodopsins.

Experimental results. The absorption properties at − 65° C. of the rhodopsins, lumirhodopsins, and metarhodopsins from five species of vertebrates are shown in Figs. 1 and 2, and summarized in Table 1. The information in each case is obtained from the type of experiment illustrated in Fig. 3.

Rhodopsin in 2 per cent aqueous digitonin is mixed with two volumes of glycerol, and to 0·3 ml. of this solution 0·005 ml. 1 *M* hydroxylamine is added. The

Table 1. Absorption Properties of the Visual Chromoproteins from Five Species of Vertebrates, measured in 2 : 1 Glycerol–digitonin at − 65° C.

Half-widths of the absorption bands are obtained, by subtraction, from the two wave-lengths or frequencies at which the extinction is half maximal

Species	$\lambda_{max.}$ (mμ)	$\varepsilon_{max.}$ (litre/mole-cm.)	Half band-width wave-length (mμ)	Half band-width frequency (10^{14}/sec.$^{-1}$)
		Rhodopsins		
Monkey	500	49,000	100	1·26
Cattle	504	47,000	96	1·17
Chicken	512	47,000	96	1·13
Bullfrog	508	46,000	98	1·17
Cusk	500	52,000	100	1·26
		Lumirhodopsins		
Monkey	500	56,000	87	1·05
Cattle	497	54,000	92	1·13
Chicken	513	49,000	94	1·09
Bullfrog	515	43,500	106	1·23
Cusk	519	54,000	96	1·09
		Metarhodopsins		
Monkey	482	48,000	83	1·09
Cattle	481	50,000	86	1·14
Chicken	489	38,000	83	1·05
Bullfrog	482	49,000	91	1·18
Cusk	507	39,000	108	1·30

solution and a blank of 2 : 1 glycerol–digitonin are cooled to − 65° C. in the modified, insulated cell compartment of a Beckman *DU* spectrophotometer, by circulating through Beckman thermospacers acetone from a reservoir chilled with solid carbon dioxide. The temperature in the cell compartment is measured with an iron-constantan thermocouple attached to the Beckman cell holder (reference junction at 0° C.). The absorption spectrum of the rhodopsin preparation is measured (Fig. 3, spectrum 1), and the rhodopsin is then irradiated in place in the cell compartment until all spectroscopic changes are essentially completed (Fig. 3, spectrum 2). The irradiation is performed with light from a 100-watt

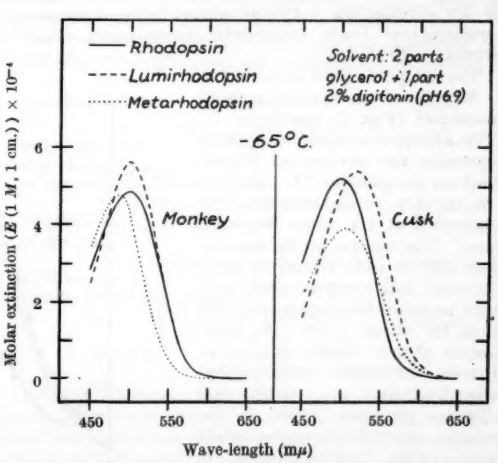

Fig. 2. Absorption spectra of rhodopsins, lumirhodopsins and metarhodopsins from monkey (*Rhesus*) and cusk (*Brosme brosme* Müller). Spectra obtained as in Fig. 1. Monkey rhodopsin was prepared by incubating rod outer limbs, isolated from light-adapted, frozen and thawed retinas, with excess neo-*b* retinene (refs. 8 and 10). The rods were then washed with buffer and water, hardened in alum, lyophilized, and extracted with petroleum ether. Rhodopsin was finally extracted with 2 per cent digitonin. Cusk rhodopsin was synthesized in solution by incubating cusk opsin, extracted from isolated rod outer limbs, with a limiting amount of neo-*b* retinene (refs. 4 and 16)

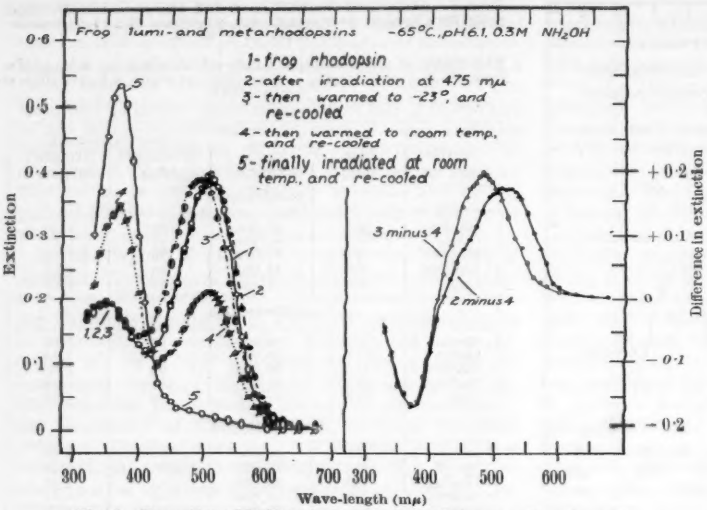
Frog lumi- and metarhodopsins -65°C., pH 6.1, 0.3M NH2OH
1- frog rhodopsin
2- after irradiation at 475 mμ
3- then warmed to -23°, and re-cooled
4- then warmed to room temp. and re-cooled
5- finally irradiated at room temp. and re-cooled
3 minus 4
2 minus 4
Extinction
Difference in extinction
Wave-length (mμ)

Fig. 3. Formation of bullfrog lumi- and meta-rhodopsin. Experimental details are described in the text. The sample was irradiated 1 hr. at 475 mμ (half band-width about 6 mμ)

zirconium arc, dispersed by a Bausch and Lomb grating monochromator (1,200 lines per mm., 250 mm. focal length), which enters the cell compartment through a window, on opening a photographic shutter.

Prolonged irradiation at − 65° C. produces mixtures composed of lumirhodopsin, photoregenerated rhodopsin, and isorhodopsin (Fig. 3, spectrum 2). Upon warming the mixture in the dark to between about − 30° and − 20° C., the lumirhodopsin is converted to metarhodopsin, whereas the other two components remain unchanged. This change in temperature is achieved by shutting off the flow of cold acetone until the desired temperature is reached, and maintaining it either with sporadic bursts of cold acetone, or by circulating ethylene glycol from a constant-temperature bath (American Instrument Co.) at about − 30° C.

The sample is then re-cooled to − 65° C., and the spectrum again measured (Fig. 3, spectrum 3). (The absorption spectra of these pigments are somewhat dependent on temperature[1,6]. Successive spectra must therefore be compared at the same temperature.) The sample in its absorption cell is now removed from the cold cell compartment, and kept at room temperature in the dark for about ½ hr. As mentioned above, under these conditions vertebrate metarhodopsins hydrolyse to opsin and *all-trans* retinene, which in the present experiments immediately reacts with hydroxylamine to form retinene oxime[7]. After re-cooling the solution to −65° C. (Fig. 3, spectrum 4), one observes the absorption bands of retinene oxime ($\lambda_{max.}$ 369 mμ), and rhodopsin and isorhodopsin, the latter having previously been masked by lumi- and meta-rhodopsin. Rhodopsin and isorhodopsin are finally converted to all-*trans* retinene oxime by irradiation at room temperature (Fig. 3, spectrum 5).

Fig. 3 (right) shows the difference spectra of bull-frog lumi- and meta-rhodopsin, obtained by subtracting spectrum 4 from spectra 2 and 3. Since these difference spectra are measured in the presence of hydroxylamine, they are equivalent to absorption spectra at wave-lengths longer than about 450 mμ, at which retinene oxime has negligible absorption[8]. All the results in Figs. 1 and 2 were obtained from this type of experiment.

That the product of irradiating rhodopsin in the cold is not a single substance, but such a mixture of chromoproteins as we have described, is further demonstrated in Fig. 4. Here cattle rhodopsin at −65° C. is irradiated at 450 mμ or 500 mμ. It is clear that the absorption spectra of the resultant products (spectra 2) depend upon the wave-length at which they are produced[2]. After warming the products, to convert lumirhodopsin to all-*trans* retinene oxime (spectra 3), one sees that the difference in spectrum is caused by a difference in composition: irradiation at longer wave-lengths favours the production of isorhodopsin (the component which absorbs at shortest wave-lengths ($\lambda_{max.}$ 490 mμ at − 65° C.)), whereas irradiation at shorter wave-lengths favours rhodopsin (see also Fig. 6 of ref. 2). Lumirhodopsin, in both cases, possesses a difference spectrum of the same shape and $\lambda_{max.}$ (Fig. 4, right).

Discussion. The shapes and wave-length maxima of the absorption spectra of the chromoproteins from the five vertebrates we have examined are summarized in Fig. 5. As can be seen from Fig. 5 and

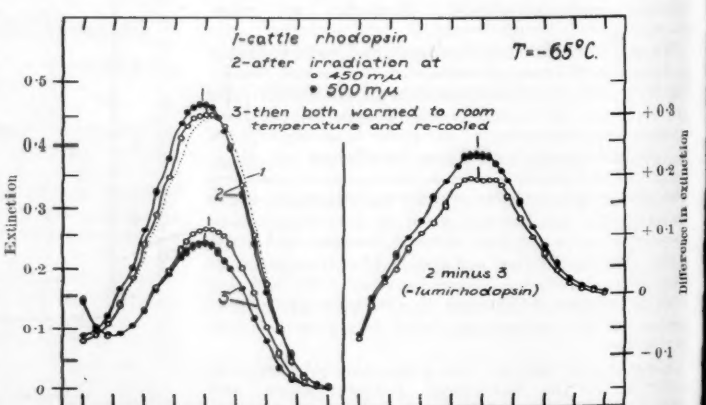

Fig. 4. Mixtures of chromoproteins obtained by irradiating cattle rhodopsin at 450 and 500 mμ. Experimental details are described in the text. Irradiation at 450 mμ was continued 1½ hr.; at 500 mμ, 1 hr.; both at half band-widths of about 6 mμ. Neither irradiation was sufficiently long to yield the steady state mixture of chromoproteins (cf. refs. 2 and 3)

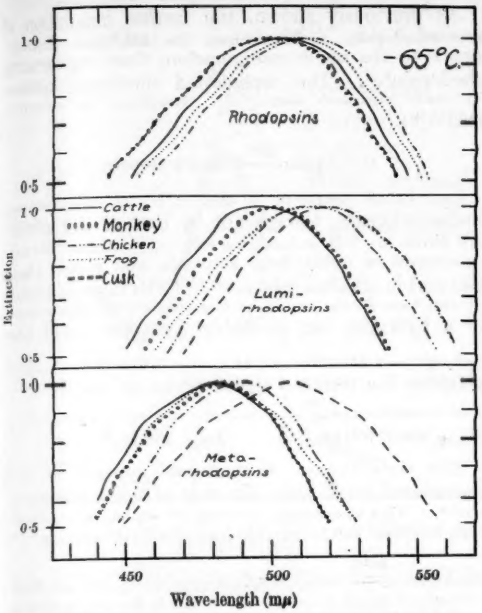

Fig. 5. Absorption spectra of the visual chromoproteins from five species of vertebrates. For comparison, all spectra are brought to an extinction of 1·0 at $\lambda_{max.}$

Table 1, the half-widths of the absorption bands (particularly on a frequency basis) exhibit little, if any, species variation, and furthermore are similar for all three classes of pigments. (The most outstanding exception is cusk metarhodopsin, and for the following reason. Metarhodopsins from different species differ somewhat in their thermostabilities. Thus, frog and especially cusk metarhodopsins hydrolyse more readily than the others. In the experiments with cusk chromoproteins, it is therefore difficult to find a temperature at which lumirhodopsin is converted completely to metarhodopsin, before some of the metarhodopsin has already hydrolysed to retinene and opsin. It is therefore likely that the spectrum of cusk 'metarhodopsin' in fact represents a mixture of lumi- *and* meta-rhodopsin. This would account for its width, and for the fact that its $\lambda_{max.}$ lies at a considerably longer wave-length than those of the other metarhodopsins.)

That $\lambda_{max.}$ varies with species is obvious for all three pigments. We have suggested elsewhere that the colour of the visual chromoproteins depends on an intimate steric fit between the chromophore and the opsin, which permits them to interact in such a way as to increase the resonance stabilization of the first excited state of the chromophore[3,9]. Species differences in the opsins modify the colours of these compounds, presumably by affecting these steric relationships with the chromophore.

The sets of chromoproteins from any one species exhibit some regularities. Thus, $\lambda_{max.}$ of lumirhodopsin in general lies at the same or longer wave-length as that of the corresponding rhodopsin; and always at a longer wave-length than that of the corresponding metarhodopsin.

We have postulated that the transformation of rhodopsin to lumirhodopsin involves, primarily, a configurational change of the chromophore; the transformation of lumirhodopsin to metarhodopsin, a change in configuration of the opsin[3]. In brief, this conclusion is based on the following arguments.

At the temperatures at which lumirhodopsin is stable (that is, below about − 45° C.), the glycerol–digitonin system forms a highly viscous liquid, or glass, which melts over the temperature-range in which lumirhodopsin changes to metarhodopsin. In the glass at low temperatures, the opsin probably has little or no freedom to change configuration, so that one can isolate the primary photochemical event —the photoisomerization of the chromophore. As the temperature is raised, however, the opsin becomes re-arranged to a new, more stable configuration.

Numerous lines of evidence indicate that the configuration of the protein is different in rhodopsin and opsin[10–12]. Furthermore, it has been shown with the squid chromoproteins that opsin reacts differently in rhodopsin and metarhodopsin[13]. This suggests that the polypeptide chain of opsin assumes one configuration in the presence of the 11-*cis* chromophore (rhodopsin), another in combination with the all-*trans* chromophore (metarhodopsin), and a third in the absence of a chromophore (opsin). When, as a result of irradiation at − 65° C., the *cis* chromophore of rhodopsin is isomerized to all-*trans* (lumirhodopsin), the configuration of the protein is unstable, but cannot become rearranged to that of metarhodopsin until the system is rendered more fluid by raising the temperature.

A further observation is in line with the above interpretation. Rhodopsin and lumirhodopsin are freely interconvertible by irradiation at − 65° C., as shown above. Likewise, rhodopsin and metarhodopsin are readily interconverted by irradiation at − 20° C.[2,3]. However, we find that *irradiation of metarhodopsin at − 65° C. does not yield rhodopsin*, just as irradiation of rhodopsin at this temperature fails to yield metarhodopsin. We conclude that the low temperature blocks re-arrangement of opsin *in both directions*. A thermal loosening of structure is required to render the two states interconvertible.

The reaction sequence involved in the bleaching of vertebrate rhodopsin can be summarized as follows:

Reaction	Product	Colour
	RHODOPSIN (11-*cis*)	red
1. Photochemical stereoisomerization of the chromophore	⇅	
	LUMIRHODOPSIN (all-*trans*)	red to purple
2. Thermal rearrangement of the opsin	↓	
	METARHODOPSIN (all-*trans*)	orange to red
3. Hydrolysis of the chromophore from opsin	↓	
	RETINENE (all-*trans*)	yellow
	+	
	OPSIN	

Species differences in opsin introduce minor differences in the absorption properties and thermal stabilities of the individual chromoproteins; but the general scheme is the same for all the vertebrate rhodopsins we have examined.

As mentioned above, visual excitation almost surely precedes the release of retinene, and apparently is triggered by the transformation of rhodopsin to lumi- or meta-rhodopsin. The rearrangement of the protein in going from lumi- to meta-rhodopsin could conceivably be the triggering reaction, perhaps by unmasking new reactive groups, or changing the

charge distribution of the molecule, and so producing a transient, localized pocket of positivity or negativity in the rod outer limb.

The experiments described in the present and two succeeding communications were performed with the financial support of grants to Prof. George Wald from the Rockefeller Foundation, the Office of Naval Research, and the Division of Neurological Diseases and Blindness of the U.S. Public Health Service (Grant *B*-568 *C*4); and while one of us (A. K.) was Fellow in Cancer Research of the American Cancer Society. We should like to thank Prof. George Wald for many helpful discussions and suggestions. We are grateful to Eli Lilly and Co., of Indianapolis, for supplying us with monkey eyes; and to the Phillips Poultry Supply, of East Boston, for gifts of fresh chicken heads.

Lumi- and Meta-rhodopsins of Squid and Octopus

By Dr. ALLEN KROPF, PAUL K. BROWN and Dr. RUTH HUBBARD

We have extracted rhodopsins from four species of invertebrates: three cephalopods, namely, squid (*Loligo pealii*)[16,17], cuttlefish (*Sepia officinalis*)[16], and octopus (*Octopus vulgaris*)[16], and one decapod crustacean—the lobster (*Homarus americanus*)[19]. These rhodopsins, like those of vertebrates, are composed of neo-*b* (11-*cis*) retinene attached as chromophore to colourless proteins, members of the family of opsins[8,12,19]. Light isomerizes the *cis* chromophore to the all-*trans* configuration, so transforming invertebrate, like vertebrate, rhodopsins to the all-*trans* chromoproteins, lumi- and meta-rhodopsin[8,13] (see also first communication). However, whereas vertebrate metarhodopsins readily hydrolyse to all-*trans* retinene and opsin[1,2] (see also first communication) the four invertebrate metarhodopsins which have been examined are relatively stable[13,17–19].

As previously shown, the further irradiation of metarhodopsin re-isomerizes its all-*trans* chromophore to the neo-*b* configuration, thus regenerating rhodopsin[8,13]. The cephalopod rhodopsin systems in their simplest form can therefore be summarized[13,16]:

$$\text{rhodopsin} \xrightleftharpoons{\text{light}} \text{metarhodopsin}$$

One other property is shared by the cephalopod metarhodopsins, though not by that of the lobster. All three are *p*H indicators, red ($\lambda_{max.}$ about 500 mμ) in neutral or mildly acid solution, and yellow ($\lambda_{max.}$ 380 mμ) in alkaline solution[13,16]. The interconversion of the two forms involves the reversible dissociation of a hydrogen ion, probably from the Schiff base linkage ($-CH=N- + H^+ \rightleftharpoons -CH=\overset{+}{N}H-$), which attaches the retinene chromophore to opsin[3,9,13,20]:

$$\underset{(\lambda_{max.}\text{ about }500\text{ m}\mu)}{\text{acid metarhodopsin}} \rightleftharpoons \underset{(\lambda_{max.}\ 380\text{ m}\mu)}{\text{alkaline metarhodopsin}} + H^+$$

The chromophore of rhodopsin appears to be a protonated Schiff base, like that of acid metarhodopsin[3,9]. The rhodopsin system of cephalopods therefore includes the reversible loss of a hydrogen ion[13,16]:

$$\text{rhodopsin} \xrightleftharpoons{\text{light}} \text{acid metarhodopsin} \xrightleftharpoons{-H^+} \text{alkaline metarhodopsin}$$

(acid metarhodopsin: light; alkaline metarhodopsin: $+H^+$; rhodopsin: light + H^+)

Preliminary experiments at low temperatures (− 45° C.) suggested that squid rhodopsin, like those of vertebrates, is converted by light to lumirhodopsin, and that a second, thermal reaction turns the latter into metarhodopsin[21]. We have investigated the lumi- and meta-rhodopsins from two cephalopods, squid and octopus, by the methods described in the preceding communication.

Experimental results. Squid rhodopsin in alkaline solution (2 : 1 glycerol–digitonin, *p*H 10) is chilled to −65° C. (Fig. 6, spectrum 1). Upon irradiation, the absorption spectrum changes as shown in Fig. 6: the extinction falls at wave-lengths shorter than 510 mμ, and rises at longer wave-lengths, owing to the formation of a mixture of chromoproteins, namely, lumirhodopsin, regenerated rhodopsin, and isorhodopsin (first communication). If this mixture is warmed in the dark to −20° C., rhodopsin and isorhodopsin remain unchanged, but lumirhodopsin at this *p*H is converted to alkaline metarhodopsin ($\lambda_{max.}$ 380 mμ), as shown in spectrum 3 (Fig. 6). The difference spectrum of lumirhodopsin, obtained by subtracting spectrum 3 from 2, is shown at the right of the figure. Since alkaline metarhodopsin has essentially no absorption at wave-lengths longer than about 500 mμ (cf. Fig. 8), above that wave-length this difference spectrum is equivalent to the absorption spectrum of lumirhodopsin.

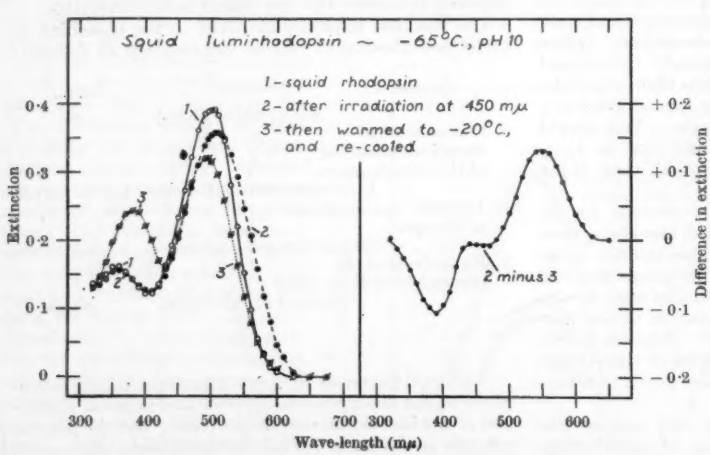

Fig. 6. Formation of squid lumirhodopsin, and its conversion to alkaline metarhodopsin. Squid rhodopsin in 2 per cent aqueous digitonin, prepared as previously described (ref. 13), was mixed with two volumes of glycerol and brought to *p*H 10 by addition of solid sodium carbonate. The solution was cooled to − 65° C. in the Beckman spectrophotometer (see first communication), and its spectrum measured against a blank of 2 : 1 glycerol–digitonin (spectrum 1). The preparation was then irradiated 2 hr. at 450 mμ (half band-width about 6 mμ), and its spectrum re-measured (spectrum 2). To convert lumirhodopsin to metarhodopsin, the solution was warmed to − 20° in the dark for about an hour, and its spectrum measured after cooling to − 65° C. (spectrum 3). Upon subtracting spectrum 3 from 2, one obtains the difference spectrum of lumirhodopsin, shown at the right

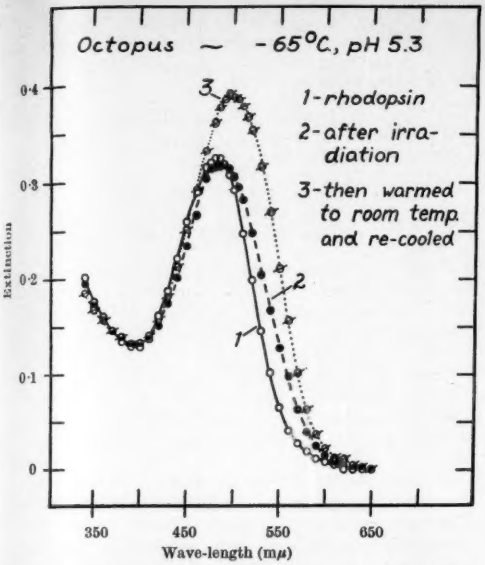

Fig. 7. Formation of octopus lumirhodopsin, and its conversion to acid metarhodopsin. Octopus rhodopsin in 2 per cent aqueous digitonin was prepared from eyes of frozen and thawed Portuguese octopus as previously described (ref. 18), and mixed with two volumes of glycerol. It was then brought to *p*H 5·3 by addition of 0·005 ml. 1 *M* acetate buffer (*p*H 4·7) to 0·3 ml. of solution, cooled to − 65° C., and its spectrum measured against 2 : 1 glycerol–digitonin as blank (spectrum 1). It was then irradiated 1 hr. at 470 mμ (6 mμ half band-width) and the spectrum remeasured (spectrum 2). The solution was now warmed to room temperature to convert lumirhodopsin to acid metarhodopsin, and the spectrum measured after re-cooling (spectrum 3). The increase in extinction at wave-lengths longer than about 450 mμ is due to the conversion of lumirhodopsin to acid metarhodopsin

The same experiment, performed with octopus rhodopsin, yields similar results, differing only in spectroscopic detail, since the absorption spectra of the chromoproteins from squid and octopus differ somewhat (cf. Table 2, and Figs. 8 and 9).

As with the vertebrate systems, the relative amounts of each isomeric chromoprotein in the mixture vary following irradiation at different wave-lengths. But the spectrum of each component—lumirhodopsin, rhodopsin, and isorhodopsin—is independent of the conditions under which it is produced (first communication).

Irradiation of squid or octopus rhodopsin at − 65° C. in neutral or mildly acid solution yields mixtures of chromoproteins identical with those obtained in alkaline solution. However, warming under these conditions converts lumirhodopsin to acid rather than alkaline metarhodopsin. In other words, the absorption spectra of the cephalopod lumirhodopsins are invariant with *p*H. Indicator properties appear only at the level of metarhodopsin. An experiment with octopus rhodopsin at *p*H 5·3 is shown in Fig. 7.

(It should be noted that *p*H is always measured above 0° C., leaving one to surmise from this the hydrogen ion concentrations at − 20° and − 65° C. The fact that squid and octopus metarhodopsins exhibit the usual *p*H indicator properties at − 20° C. serves as something of an internal check on the *p*H of the system at that temperature. Another indication that the difference in hydrogen ion concentration between the acid and alkaline samples is maintained at least to some extent at the low temperatures is offered by the fact that acid or alkaline metarhodopsin, prepared above 0° C., maintains its identity upon lowering the temperature to − 20°, and − 65° C. (compare Fig. 3 of ref. 2 with Fig. 8 herewith).)

The absorption properties of the chromoproteins from squid and octopus, obtained from the types of experiment shown in Figs. 6 and 7, are summarized in Figs. 8 and 9, and in Table 2. The absorption spectrum of octopus alkaline metarhodopsin has not been included because it closely resembles that of the squid pigment.

Discussion. The absorption maximum of octopus rhodopsin lies at considerably shorter wave-lengths than that of squid rhodopsin, and this is even truer of the lumirhodopsins from the two species. Their metarhodopsins, however, are almost identical. The spectroscopic picture of the conversion of lumirhodopsin to acid metarhodopsin is therefore quite different with the two animals. In the squid, lumirhodopsin

Table 2. Absorption Properties of Rhodopsin, Lumirhodopsin, and the Metarhodopsins from Squid (*Loligo pealii*) and Octopus (*Octopus vulgaris*) in 2 : 1 Glycerol–Digitonin at − 65° C. Half-widths of absorption bands, determined as described in the first communication, are given in terms of wave-length (mμ) and frequency (sec.$^{-1}$)

Absorption characteristics	Rhodopsin	Lumi-rhodopsin	Metarhodopsin Acid	Metarhodopsin Alkaline
Squid				
$\lambda_{max.}$ (mμ)	500	550	500	385
$\varepsilon_{max.}$ (litre/mole-cm.)	48,000	64,000	65,500	66,500
Half band-width : (mμ)	102	83	102	76
(10^{14} sec.$^{-1}$)	1·28	0·84	1·29	1·61
Octopus				
$\lambda_{max.}$ (mμ)	483	508	505	
$\varepsilon_{max.}$ (litre/mole-cm.)	43,000	38,000	63,000	
Half band-width : (mμ)	98	94	105	
(10^{14} sec.$^{-1}$)	1·31	1·13	1·29	

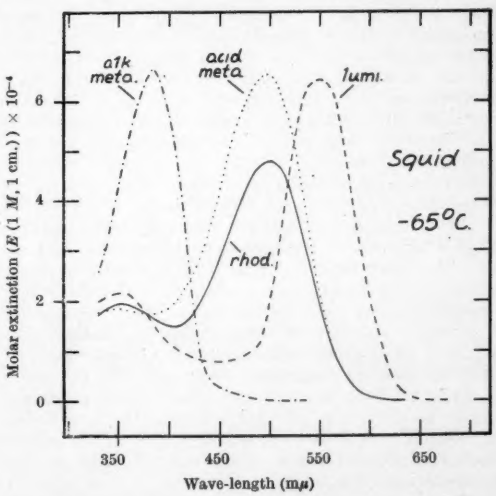

Fig. 8. Absorption spectra of squid chromoproteins in 2 : 1 glycerol–digitonin at − 65° C. The molar extinctions of rhodopsin and the two forms of metarhodopsin are derived from the extinction coefficients at + 5° C. (ref. 13), by cooling solutions of known extinction at that temperature to − 65° C., and correcting for volume shrinkage (3·7 per cent). The molar extinction of lumirhodopsin is obtained by measuring the extinction of rhodopsin which disappears when a given extinction of lumirhodopsin is formed (cf. Fig. 6). The spectrum of lumirhodopsin below 500 mμ is extrapolated by inserting the extinctions of alkaline metarhodopsin into the difference spectrum shown in Fig. 6. The results are averages from two experiments

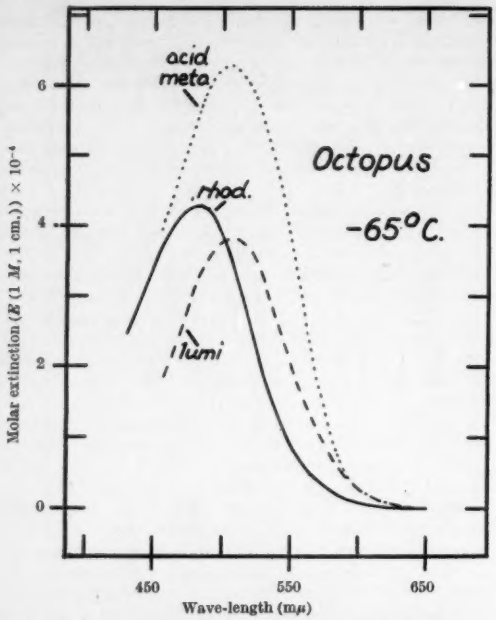

Fig. 9. Absorption spectra of octopus chromoproteins in 2 : 1 glycerol–digitonin at − 65° C. The molar extinction of rhodopsin at this temperature is obtained from that at + 2° C. (ref. 18) as described above. The absorption properties of lumirhodopsin are obtained from the type of experiment shown in Fig. 6, as described above. The absorption properties of acid metarhodopsin are derived from experiments like that shown in Fig. 7, by warming the solution containing acid metarhodopsin (Fig. 7, spectrum 3) to room temperature and raising the *p*H to about 9, to convert acid to alkaline metarhodopsin. The spectrum is then measured after re-cooling the solution to − 65° C., and the difference spectrum of acid metarhodopsin obtained in the same way as that of lumirhodopsin

and acid metarhodopsin have almost the same extinctions, and the transformation involves primarily the relatively large shift of $\lambda_{max.}$ from 550 to 500 mμ. In the octopus, the situation is reversed: $\lambda_{max.}$ remains virtually unchanged, while $\varepsilon_{max.}$ increases from 38,000 to 63,000. A possible interpretation of such species differences is discussed in the first communication.

We have mentioned previously that irradiation converts vertebrate metarhodopsin to rhodopsin at − 20° C., but not at − 65° C. (first communication). This is true also of the cephalopod pigments, and can be seen particularly clearly in interconversions between rhodopsin and alkaline metarhodopsin, because of the wide separation of their absorption maxima. Irradiation of alkaline metarhodopsin at + 5° C. yields rhodopsin and isorhodopsin[18]. We find that the same occurs at − 20° C., and *not* at − 65° C. Just as with the vertebrate pigments, the interconversion of rhodopsin and metarhodopsin is blocked in *both* directions at − 65° C. We assume this to be due to a lack of mobility of opsin at that temperature (first communication).

The observations on cephalopod pigments are consistent with our previous view that the reaction, rhodopsin→lumirhodopsin, involves a change in configuration of the chromophore, whereas the reaction, lumirhodopsin→metarhodopsin involves a configurational rearrangement of opsin (first communication). The reactions initiated by the irradiation of cephalopod rhodopsins can therefore be summarized:

Reaction	Product	Colour
	Rhodopsin (11-*cis*)	orange to red
1. Photochemical stereoisomerization of the chromophore	⇅	
	Lumirhodopsin (all-*trans*)	red to violet
2. Thermal rearrangement of the opsin	↙ −H⁺ ; ↘ −H⁺	
	Acid (red) ⇌ Alkaline (yellow)	
	(+H⁺ ; +H⁺)	
	Metarhodopsin (all-*trans*)	

Since the cephalopod visual systems do not include the hydrolysis of metarhodopsin to retinene and opsin, visual excitation of these animals must be triggered by the conversion of rhodopsin to metarhodopsin, perhaps by the second phase of this process—the conversion of lumirhodopsin to metarhodopsin—which involves configurational changes in opsin (first communication). The present experiments show that in cephalopods the transformation of lumi- to meta-rhodopsin introduces *p*H indicator properties, owing to the possibility of dissociating a hydrogen ion from the metarhodopsin chromophore. The re-arrangement of opsin could involve further changes in charge, and it is possible that such changes are the sources of visual excitation.

Chicken Lumi- and Meta-iodopsin

By Dr. RUTH HUBBARD and Dr. ALLEN KROPF

The first cone pigment was extracted from chicken retinas by Wald[23]. Although he was unable to purify and concentrate the visual pigment sufficiently to see its colour, he named it iodopsin on the basis of its absorption properties (*ion* = violet, Gr.). In the course of the present investigation, we have finally had a glimpse of pure iodopsin in sufficient concentration to confirm Wald's inference.

Like rhodopsin, iodopsin consists of neo-*b* (11-*cis*) retinene joined as chromophore to a colourless protein, an opsin[15]. The opsins of rhodopsin and iodopsin, however, differ substantially, and have been named rod opsin (or scotopsin) and cone opsin (or photopsin)[15]. The rhodopsin and iodopsin systems involve the same isomerization cycle of retinene: both photopigments are synthesized from neo-*b* retinene, and bleach in the light to all-*trans* retinene and the corresponding opsin[15].

As already noted[2,3] (see also first communication), the photochemical bleaching of rhodopsin involves a sequence of photochemical and thermal reactions, which yield as intermediates the two all-*trans* chromoproteins, lumi- and meta-rhodopsin. Using the same methods, we now find a similar sequence of reactions in the bleaching of iodopsin.

Light converts iodopsin to a first unstable product, which we call lumi-iodopsin. Above about − 45° C., this is converted in the dark to a second unstable product, meta-iodopsin. The latter hydrolyses in the dark above about − 30° C. to all-*trans* retinene and cone opsin. Furthermore, just as irradiation of lumi- or meta-rhodopsin converts it to rhodopsin by isomerizing its all-*trans* chromophore to the 11-*cis* configuration, irradiation of lumi- or meta-iodopsin re-isomerizes its all-*trans* chromophore to 11-*cis*, yielding iodopsin. A complete parallelism is seen therefore between the rhodopsin and iodopsin systems.

Experimental results. Before describing the interconversions of iodopsin with lumi- and meta-iodopsin

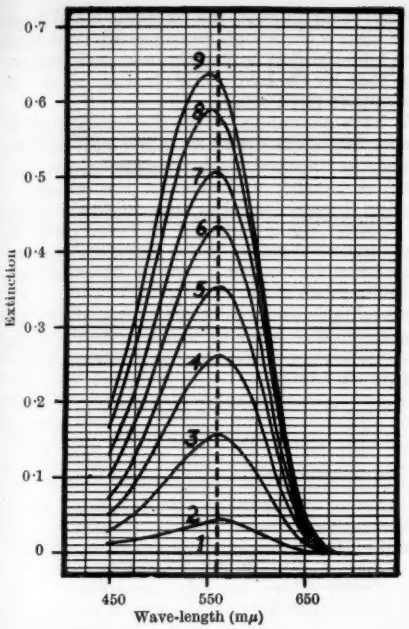

Fig. 10. Synthesis of iodopsin in aqueous 2 per cent digitonin (*p*H 6·1). The opsins (rod and cone) were extracted from light-adapted chicken retinas (ref. 15), and 0·2 ml. of the extract was balanced in the Cary recording spectrophotometer against another sample of the same solution as blank (spectrum 1). Successive portions of neo-*b* retinene (approximately 0·7 mμmol. in 0·005 ml. 1 per cent digitonin) were added, and spectra recorded 5 min. after each addition (spectra 2 to 9). Chicken cone opsin has a much greater affinity for neo-*b* retinene than rod opsin. The first five additions, therefore, resulted in the formation of iodopsin alone ($\lambda_{max.}$ 560 mμ; spectra 2–6). Further additions yielded progressively more rhodopsin ($\lambda_{max.}$ 503 mμ), as shown by the shift of $\lambda_{max.}$ toward shorter wave-lengths (spectra 7–9)

in more detail, we need to comment upon the preparation of iodopsin.

Chicken retinas contain both cones and rods, in the ratio[15] of about 8 : 1. Hence the extraction of photosensitive pigments from dark adapted retinas always yields mixtures of rhodopsin and iodopsin[15,22]. However, Wald *et al.* showed that one can obtain from light-adapted chicken retinas mixtures of the colourless rod and cone opsins, which upon incubation with neo-*b* retinene in solution yield rhodopsin and iodopsin[15]. They showed further that chicken cone opsin has a much greater affinity for neo-*b* retinene than rod opsin, so that the addition of limited amounts of neo-*b* retinene (less than needed to combine with all the available cone opsin) results in the formation of iodopsin alone, uncontaminated with rhodopsin.

We have used this method of preparation, as illustrated in Fig. 10. In the experiment shown, the first five additions of neo-*b* retinene resulted in the synthesis of iodopsin alone, with $\lambda_{max.}$ 560 mμ (curves 2–6). Further additions led to the formation of rhodopsin ($\lambda_{max.}$ 503 mμ), as shown by the shift of $\lambda_{max.}$ toward progressively shorter wave-lengths (curves 7–9).

For the experiments described below, the mixed opsins (rod and cone) from 200–250 chicken eyes were extracted by the methods of Wald *et al.*[15], and a small aliquot of each new preparation was assayed as shown in Fig. 10. The opsin stock was then mixed with less neo-*b* retinene than would saturate the cone opsin (for example, 3·5 mμ mole neo-*b* per 0·2 ml. of the opsin preparation shown in Fig. 10), and the resulting iodopsin solutions were stored frozen at − 15° C. For use, they were thawed and mixed with equal or double their volumes of glycerol, depending on the temperature at which experiments were conducted. (This way of preparing iodopsin has the manipulative advantage of letting one work in white light until the retinene is added; only then need one shift to the dim red light required to avoid bleaching iodopsin[15,22].)

Fig. 11 shows the results of irradiating such an iodopsin preparation at − 20° C. (spectrum 1) with orange light. This converts it almost completely to meta-iodopsin, with $\lambda_{max.}$ about 500 mμ (spectrum 2). Meta-iodopsin is stable below about − 35° C., but even at temperatures as low as − 20° C. it hydrolyses slowly in the dark to all-*trans* retinene and opsin. The hydrolysis is speeded at higher temperatures. The sample shown in Fig. 11 had for this reason been brought to room temperature before measuring spectrum 3.

Since the absorption spectra of iodopsin and meta-iodopsin overlap only slightly, at appropriate wave-lengths one can irradiate the one with almost no effect upon the other. As shown in Fig. 11, irradiation at 610 mμ results in a virtually quantitative conversion of iodopsin to meta-iodopsin. Conversely, by irradiation at 450 mμ, one can convert a considerable fraction of meta-iodopsin back to iodopsin, as shown in Fig. 12. Moreover, this wide separation of the absorption maxima of iodopsin and meta-iodopsin enables one to identify them, when mixed, more easily than the vertebrate rhodopsins and meta-rhodopsins produced in comparable experiments (cf. refs. 2 and 3). Otherwise, these experiments raise no new issues that have not already been discussed for rhodopsin[2,3,13] (see also first and second communications).

When iodopsin is irradiated at lower temperatures than those used in the experiments of Figs. 11 and 12, it is converted only to lumi-iodopsin. This must be warmed above about − 45° C. before it changes to meta-iodopsin. The absorption spectrum of chicken lumi-iodopsin has the same shape as those of the other chromoproteins we have described (first and second communications), and its $\lambda_{max.}$ lies at about

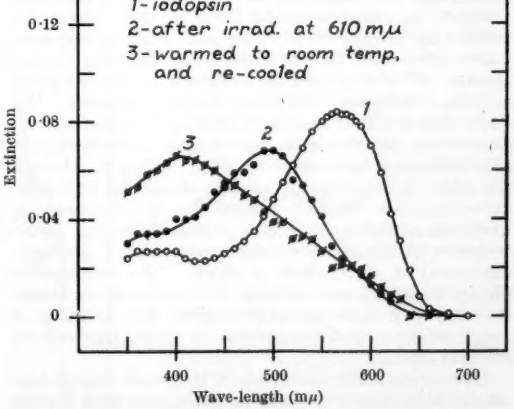

Fig. 11. Formation of meta-iodopsin, and its hydrolysis to retinene and opsin. Iodopsin in 1 : 1 glycerol–digitonin (*p*H 6·1) is cooled to − 20° C. (spectrum 1), and irradiated 20 min. at 610 mμ (half band-width 6 mμ). This converts almost all of it to meta-iodopsin, with $\lambda_{max.}$ about 500 mμ (spectrum 2). Upon warming to room temperature in the dark, the latter hydrolyses to retinene and opsin (spectrum 3)

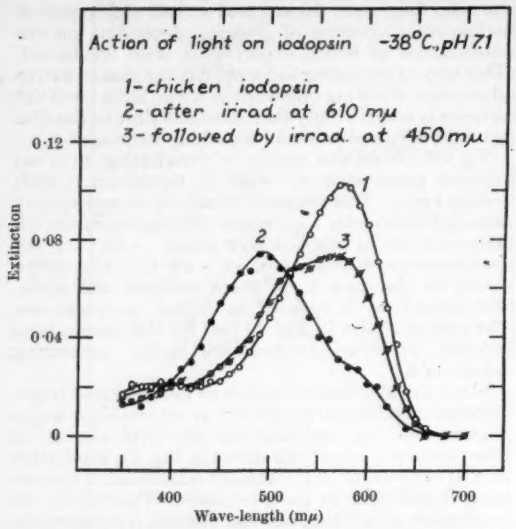

Fig. 12. Interconversions of iodopsin and meta-iodopsin. Iodopsin in 2 : 1 glycerol–digitonin (*p*H 7·1) is cooled to − 38° C. (spectrum 1) and irradiated 2 hr. at 610 mμ (16 mμ half band-width). This results in its partial conversion to meta-iodopsin (spectrum 2). The latter is now irradiated 20 min. at 450 mμ (same band-width), which converts a large fraction of it back to iodopsin (spectrum 3). Neither irradiation is sufficiently extensive to produce the steady-state mixture of chromoproteins (refs. 2 and 3). In this experiment, the temperature of the Beckman cell compartment was controlled (first communication) by circulating butyl 'Cellosolve' from a reservoir chilled with solid carbon dioxide

525 mμ. The isomeric 9-*cis* chromoprotein, isoiodopsin[15], on irradiation yields the same lumi- and meta-iodopsins as does iodopsin (cf. refs. 2 and 3).

We have made the surprising observation that the photosensitivity of iodopsin, that is, the quantum yield of photoisomerization from 11-*cis* to *trans*[2,3], decreases markedly as one lowers the temperature. (Compare, for example, the extent of conversion of iodopsin to meta-iodopsin in the experiment of Fig. 11, in which the irradiation lasted 20 min., with that shown in Fig. 12, in which the same type of irradiation was continued for 2 hr. at a higher intensity.) It is difficult to formulate this observation quantitatively, since the irradiation yields different products as one lowers the temperature. However, irradiating always at 610 mμ, and making approximate allowance for differences in the absorption spectra of the products—retinene, meta-iodopsin, and lumi-iodopsin—the effect is unmistakable. We have observed that the photosensitivity of the conversion of squid rhodopsin to alkaline metarhodopsin also decreases between + 5° and − 20° C., though the effect is considerably smaller than with iodopsin. However, we observe essentially no decrease in quantum efficiency when photoisomerizing neo-*b* retinene in the same solvent system (2 : 1 glycerol-digitonin) at + 20° and − 40° C. The decrease in photosensitivity on lowering the temperature therefore appears to be associated with the coupling of neo-*b* retinene as chromophore to opsin, particularly to cone opsin.

Discussion. The bleaching of rhodopsin and iodopsin by light proceeds over intermediates with similar chemical and spectroscopic properties (lumi- and meta-pigments) and results finally in the release of all-*trans* retinene and opsin. It is reasonable to assume that the photochemical and thermal reactions involve the same type of change in both classes of pigment—that in both the photochemical isomerization of the *cis* chromophore to the all-*trans* configuration is followed first by the thermal re-arrangement of opsin, then by the hydrolytic cleavage of the all-*trans* chromophore from opsin.

We have postulated that the configurational rearrangement of the opsins from the lumi- to the meta-pigments is blocked at low temperatures by their structural rigidity and that of the solvent. It is tempting to speculate that this rigidity of the opsins also imposes configurational barriers which restrain the photoisomerization of the chromophore, and thus are responsible for the observed decrease in photosensitivity.

By analogy with the schemes proposed for the action of light on rhodopsins (first and second communications), we can summarize our observations with chicken iodopsin as follows :

Reaction	Product	Colour
	Iodopsin (11-*cis*)	violet
1. Photochemical stereoisomerization of the chromophore	⇅	
	Lumi-iodopsin (all-*trans*)	purple
2. Thermal rearrangement of the opsin	↓	
	Meta-iodopsin (all-*trans*)	red
3. Hydrolysis of the chromophore from opsin	↓	
	Retinene (all-*trans*) + Opsin	yellow

The absorption maximum of chicken iodopsin lies at a considerably longer wave-length than those of the rhodopsins. We assume that this is due to stronger interactions (owing in part, perhaps, to a closer steric fit) between the neo-*b* chromophore and cone as compared with rod opsin[9]. The absorption properties of lumi- and meta-iodopsin, on the other hand, are not very different from those of the corresponding rod chromoproteins (first and second communications). This suggests that photoisomerization of the retinene chromophore to the all-*trans* configuration tends to equalize the degree of its interaction with rod and cone opsin.

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LETTERS TO THE EDITORS

GEOPHYSICS, ASTRONOMY and METEOROLOGY

Cosmic Radiation and the Weather

THE purpose of this communication is to point out the existence of a large tropospheric and stratospheric effect produced by the solar-cycle modulation of cosmic rays. Since there is some evidence for solar-cycle correlations in the weather, the phenomena described here should be considered in attempts to understand climatological effects of solar-cycle period.

The records of Forbush[1] for the ionization produced by cosmic rays at the ground show through two solar cycles in inverse correlation with solar activity; that is, if one compares sunspot numbers with cosmic-ray ionization at sea-level, it is found that high sunspot numbers are associated with low cosmic-ray ionization (see Fig. 1). Neher and Winckler[2,3] have shown that ion chambers at the top of the atmosphere show a very much larger modulation with the solar cycle than the instruments at sea-level. The change in ionization at 10 mb. is bound to be approximately a 50 per cent reduction between sunspot minimum and sunspot maximum. That this change in ionization is produced by a true cosmic-ray modulation was demonstrated by the study of primary cosmic-ray alpha-particles by Freier, Ney and Fowler[4], who found that the change in the flux of primary helium nuclei with energy greater than 200 MeV./nucleon was 50 per cent at the top of the atmosphere, in quantitative agreement with the ionization measurements of Neher and Winckler. Because the solar-cycle modulation changes the flux of low-energy particles more than the flux of high-energy particles, the change in the atmosphere due to ionization must show a latitude effect. (This effect is produced by the selective effect of the Earth's magnetic field on primary cosmic rays. For example, at the equator, in the vertical direction, only cosmic-ray protons of energy greater than 15 BeV. can reach the Earth, whereas at the magnetic poles cosmic rays of all energies can arrive.) The relation between cosmic-ray flux and atmospheric ionization is quite well understood, and it is therefore possible to construct a graph showing the percentage change in atmospheric ionization as a function of altitude and latitude. In order to do this, one combines the results of sea-level ion chambers and the balloon observations to give a profile of the ionization through the atmosphere.

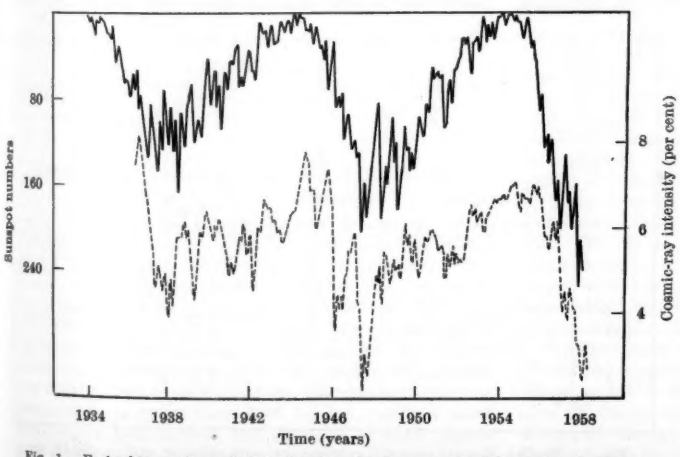

Fig. 1. Forbush's results ref. (1) showing the inverse correlation of cosmic-ray intensity and solar activity. ———, Sunspot numbers; - - - -, cosmic-ray intensity

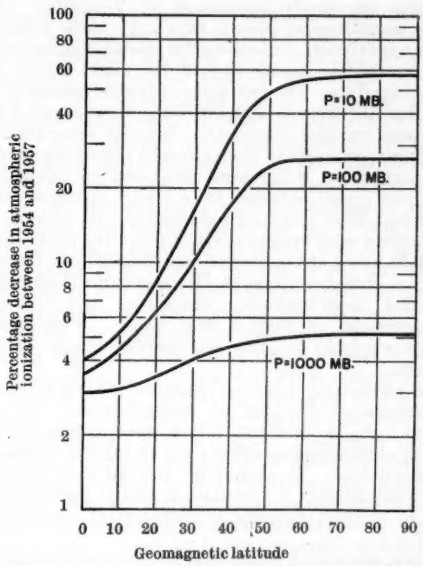

Fig. 2. Percentage reduction in atmospheric ionization during the last solar cycle. The percentage change is calculated with respect to the value of the ionization at sunspot minimum in 1954

Fig. 2 shows the result of using the cosmic-ray observations to determine the percentage change in world-wide ionization. The percentages plotted show the amount by which the ionization was reduced from 1954 (sunspot minimum) to 1957 (sunspot maximum). Note that the latitudes plotted are geomagnetic rather than geographic. The percentages are $\frac{I_{1954}-I_{1957}}{I_{1954}}\times 100$, where I_{1954} represents the ionization in 1954, and I_{1957} that in 1957.

It can be seen from Fig. 2 that even in the troposphere a relatively large percentage change in the ionization occurs. If there is a connexion between atmospheric ionization and thunderstorm activity, for example, the solar-cycle modulation might be observed in the climatological data. A relation between ionization and weather

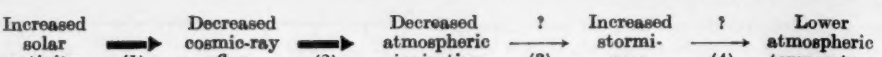

Fig. 3

has been previously postulated by Vonnegut. The known variations of cosmic rays may allow a test of such a hypothesis. In looking for climatological variations, a further point should be made about the cosmic-ray data. The two solar cycles measured so far show that the largest changes occur during one or two years near sunspot maximum. Because solar activity rises relatively rapidly from sunspot minimum to sunspot maximum, differences produced by ionization should be great between 1954, 1955 (sunspot minimum) and 1957 (sunspot maximum). In looking for correlations over long periods of time, the most easily available index of the cosmic-ray ionization is the sea-level ion-chamber data at the equator (Huancayo), and the high-latitude ionization and neutron measurements of Fenton and Rose[5]. This should be one variable in any correlation study of this problem.

The cosmic-ray changes observed by Forbush and the calculated changes in ionization rest on firm ground. It is perhaps worth speculating on the kind of climatological effects the change in ionization might produce. It should be pointed out, however, that what follows is speculation and is included here only to suggest possible climatological variables to study.

If one assumes a connexion between ionization and storminess, for example, one might also expect a correlation of Earth temperature and the sunspot cycle. It seems reasonable to postulate that a lowered conductivity of the air (making it a better insulator) might enhance the build-up of electric fields and thereby increase storminess (at least thunderstorms). The increased cloud cover associated with the storms would produce radiation cooling of the Earth and a lower mean temperature at sunspot maximum. One might therefore account qualitatively for Humphrey's paradox of the 'hot sun and the cool Earth'. The suggested chain of events is shown diagrammatically above in Fig. 3.

The heavy connecting arrows show the established relations (1) and (2). The question mark on step (3) shows the speculative connexion between ionization and storminess. Relation (4) is also shown with a question mark, because it does not rest on firm observational grounds as do (1) and (2).

Obviously the chain of events suggested is just an example, and climatologists should be able to construct many such possible patterns which could be tested against the cosmic ray – variation of weather hypothesis.

In summary, it should be emphasized that the meteorological variable subject to the largest solar-cycle modulation in the denser layers of the atmosphere (that is, at pressures greater than 1 mb.) is the atmospheric ionization produced by cosmic rays. It seems, therefore, worth while to investigate the possible effects of the change in this variable in climatology.

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Measurement of Horizontal Displacement along Faults in the Ocean Floor

In the eastern Pacific Ocean a right lateral displacement of 84 nautical miles along the Murray Fracture Zone[1] has been suggested by a total magnetic intensity survey[2,3]. The Pioneer Ridge, a newly found east–west fault located between the Mendocino and the Murray Fractures along 38° 30′ north latitude and known to extend between 127° and 136° west longitude, was surveyed by the R.V. *Horizon* of the Scripps Institution of Oceanography of the University of California for the express purpose of measuring the direction and the amount of horizontal slip. A left lateral displacement of 138 nautical miles was found.

The method of measurement depends on the fortunate fact that the magnetic anomaly pattern of the ocean floor revealed by surveys which extend from 32° to 41½° N. lat. and from 125° to 135° W. long., is characterized by north–south trending features with a relief of several milligauss. The two lower curves in Fig. 1 are 15 miles apart and show the north–south alignment of the magnetic pattern. The east–west fractures cut across this pattern so that horizontal slip along a fracture produces a displacement. This is shown in Fig. 1 by a comparison of the uppermost profile taken north of Pioneer Ridge with the lower pair taken to the south. The uppermost profile is roughly 70 miles north and far to the west.

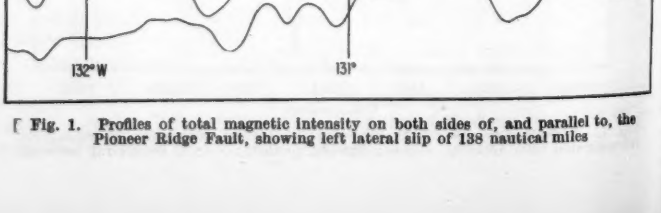

Fig. 1. Profiles of total magnetic intensity on both sides of, and parallel to, the Pioneer Ridge Fault, showing left lateral slip of 138 nautical miles

A left lateral fault with a displacement of 138 nautical miles is required to match the pattern. The goodness of fit shows that the amount of distortion accompanying this left lateral slip over a length of 90 miles was less than 10 per cent and implies a remarkable freedom of movement of one crustal block with respect to the other.

The measured displacements along the Murray Fracture Zone and the Pioneer Ridge reveal an unsuspected mobility of small blocks of oceanic crust.

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Planetary Nebulæ in the Large Magellanic Cloud

PLANETARY nebulæ have been found in the Andromeda Nebula[1] and in the Small Magellanic Cloud[2]. A new catalogue of emission objects in the Small Cloud to be published shortly by me contains nearly six hundred objects; fifty-three of these are planetary nebulæ. Using the Armagh–Dunsink–Harvard telescope and prism with 103*a.E* red-sensitive plates exposed through a red filter, a planetary nebula is readily recognized by a single H_α emission line with no continuum and not associated with nebulosity.

This method has now been applied to the Large Magellanic Cloud. The observational programme is not quite completed and the plates taken have been only provisionally examined. Nearly one thousand emission objects have been found on these plates; at least 120 of these are planetary nebulæ. Where blue-sensitive prism plates are available and the objects are bright enough confirmation as planetaries is provided by the N_1 N_2 nebular lines of O III. The presence of planetary nebulæ presents additional evidence of Population II objects in the Large Cloud.

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Armagh Observatory,
Northern Ireland. Dec. 30.

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Rotational Structure of the 3914 A. N_2^+ Band in Sunlit Auroræ

ON the evenings of September 3 and 4, 1958, striking sunlit auroræ were observed from Saskatoon in the western sky. Although no photographs were taken, there can be no doubt about the nature of these displays because they showed the divided rays with greyish-coloured upper segments as described by Störmer[1], and because of the peculiarities of the spectrum. During each night of the display a plate was obtained with an *f*/0·8 Schmidt grating spectrograph having a dispersion of 40 A./mm., while a third plate was obtained from the displays of both nights with a large *f*/0·8 spectrograph having a dispersion of 20 A./mm. They were set to record the spectrum in the 3500–4500 A. region and the lines of sight of the instruments were directed towards the upper parts of the rays.

The lower dispersion spectra show unusually high relative intensities of the first negative N_2^+ bands for higher vibrational levels; this effect was first observed by Störmer and explained by Bates[2] as due to an abnormal distribution of the populations of the vibrational levels of N_2^+ resulting from the fluorescent excitation process dominant in sunlit auroræ. All three plates showed a most unusual intensity distribution in the fine structure of the 0,0 N_2^+ band at 3914 A. A microphotometer tracing of this band as photographed on the high dispersion plate is shown in Fig. 1*a*. For comparison a tracing is shown of the band from a normal aurora in Fig. 1*b*. The band from sunlit auroræ is developed to very high rotational quantum numbers, and its intensity distribution is not quite uniform from line to line. The lines of the *P* branch have crossed the zero gap and underlie the beginning of the *R* branch. The rotational temperature derived from the band by plotting log (I/K') against $K'(K'+1)$ was 2,100° K. The perturbation at the line $R(38)$ is clearly visible.

There are two possible mechanisms which might explain the high rotational temperature. First, the N_2^+ ions might be in radiative equilibrium with the sunlight; this is an extension of Bates's explanation to cover rotational as well as vibrational degrees of freedom. Second, the N_2^+ ground-state might have a rotational distribution corresponding to thermal equilibrium at some high temperature, which might or might not be the temperature of the atmosphere at the height concerned. In either case, as was pointed out by Swings[3], the presence of Fraunhofer lines in the exciting sunlight would cause the distribution of line intensities to be non-uniform, just as in the spectra of comets[4,5]. The N_2^+ molecule, being homonuclear, has no rotation or vibration-rotation spectra, so that radiative equilibrium would be established easily if collisions were not important. If the first case is to be treated properly, absorption and emission in the *P* and *R* branches of all the bands of the system must be considered at once; for the second case only the absorption is important, but some of the higher bands may still contribute since the vibrational excitation is unusually high.

The exciting intensities were estimated from the Utrecht Atlas of the solar spectrum[6] as fractions of the continuum; the continuum was considered as having a colour temperature of 7,150° K. as recommended by Minnaert[7]. The first case was treated approximately by including the (0,0) and (0,1) bands which should be the most important; their shares of the excitation are in the ratio of about 3 : 1. For the second case only the (0,0) band was included. It would be expected that inclusion of more bands would tend to smooth out the distribution of intensities obtained. The general trend of the two sets of results was very similar, but there were considerable differences in detail and the second case gave better agreement with the observations. The temperature used was 2,100° K., as described above; the agreement of the calculated and observed spectra confirmed it.

We conclude that the N_2^+ ions observed had a rotational temperature in the ground-state of 2,100° K. There seems to be no way of deciding whether this is also the temperature of the atmosphere at the height observed, except perhaps from the fact that the ions do not seem to be in radiative equilibrium with the sunlight. It is conceivable that the high temperature

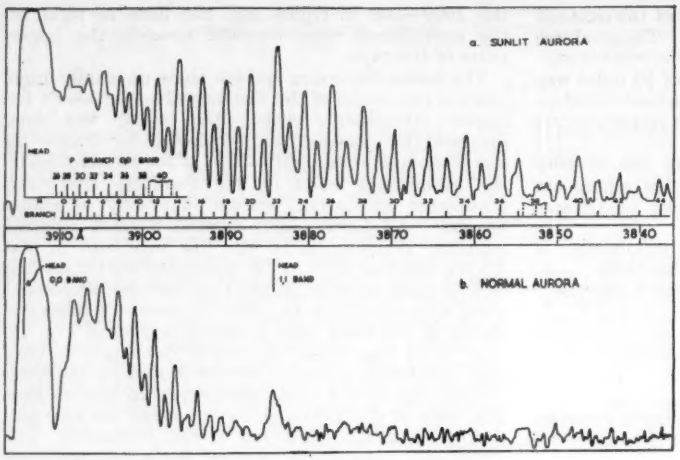

Fig. 1

could result from this mechanism, but that the distribution among the levels would be smoothed by collisions without lowering the temperature. This seems rather unlikely, especially if many of the collisions are with N_2, since charge-exchange can reduce the rotational temperature to the ambient in a single collision. It is at least possible that this observation shows a kinetic temperature of 2,100° K. at a height which is likely to be in the range 300–600 km.

The investigation reported here has been sponsored by the Geophysics Research Directorate of the U.S. Air Force, Cambridge Research Center, Air Research and Development Command, under contract 19(604)-1831.

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PHYSICAL SCIENCES

Wear of Graphite Surface by Punching and Planing

The wearing process has been studied in detail on graphite basal plane surfaces rubbed by metallic micro-probes while being observed with a microscope having epi-illumination. When the graphite was smooth and flat, the probe under very light force could be passed repeatedly over the graphite without damage. Under increasing normal force, however, the surface showed a few sharp shadow lines extending away from the contact region, and these were interpreted as boundaries of stress or dislocation within the crystal.

Upon sustaining the contact pressure at a site showing such lines, by stopping the motion, it was found that the basal plane surface sometimes collapsed locally, in time-dependent manner. Instantaneously with the collapse the lines disappeared, and a tiny scar was found when the probe was moved away.

The scars were very shallow and in appearance resembled a hole in a skating rink with chips lying at the borders. It was evident that a graphite fragment had been punched out of a basal plane layer, and remained tilted against it if not completely pushed aside. When the probe was slid away from a scar, a wear track almost invariably began at the first pass and continued without diminishing.

These wear tracks were characteristically uniform in width and depth so that long straight lines of ruled geometry were easily drawn. The debris in the form of thin platelets was rather cleanly swept to the borders of a track and could sometimes be fitted back into it.

This type of wear was seen to occur through a planing of the basal plane surface. It appeared that the metallic probe itself could produce the wear track by penetration of the basal plane at the scar, or that the probe could trap a graphite fragment from the scar, which fragment then served as a secondary tool for the planing. It is easily imagined that the edges of such a fragment would tend to engage the opened edges of the scar so that a continuous wearing process would inevitably follow.

Wear by planing also started when the probe passed from smooth basal plane surface across a step (in the range 10^{-4}–10^{-5} cm. height), either upward or downward. In the first instance the basal plane was penetrated directly by passage of the probe against the riser of the step. In the second instance the probe usually produced a fragment by local collapse of the edge of the step under pressure at the descent. In both instances a continuous wearing process followed.

In these instances of wear by planing, the graphite surface was continuously delaminated by the tool. A characteristically different wearing process, also in the graphite basal plane, will be called 'peeling', and will be described in a later publication.

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Metallic Conduction in the Crystal Compounds of Graphite

A marked increase of electrical conductance on forming crystal compounds of graphite with bromine, and even more with alkali metals such as potassium, has been previously attributed to electron transfer between the carbon hexagon networks, acting as amphoteric macro-aromatic molecules, and the intercalated atoms[1]. It was further suggested that the bonds between these macro-aromatic molecules and atoms such as potassium were metallic in character. Existing evidence indicated that electron transfer is less complete than when salts are formed with

systems more strongly electro-negative than the carbon macromolecules (cf. also ref. 2). However, development of this interpretation has been hindered by the need to experiment with polycrystalline graphite, either as powder or in compacted forms[3].

Recently, we have been able to carry out experiments on pieces of graphite in which the preferred orientation of the carbon hexagon networks is so good that the results permit definite inferences about the behaviour of single crystals, and in particular about the anisotropy of the electronic properties along the *a*- and *c*-axes of graphite. By courtesy of the Morgan Crucible Co., pieces of 'columnar' graphite have been made available in which individual crystallites show excellent alignment of their *a*-axes parallel to the columnar axis, though their *c*-axes are disordered radially. By developing a method of depositing graphite by cracking methane[4], we have also had available pieces of graphite in which individual crystallites show excellent alignment of their *a*-axes parallel to a plane, and of the *c*-axes normal to it. Pieces of these materials several millimetres across in all dimensions have been mounted between 4-point platinum electrodes, so as to measure the electrical resistance parallel to the *a*-axis and parallel to the *c*-axis of the crystallites in the highly oriented material. Preliminary selection permitted the use of graphite with *a*-axis specific resistance as low as $3{\cdot}6 \times 10^{-5}$ ohm cm. (columnar natural graphite) and $4{\cdot}75 \times 10^{-5}$ ohm cm. (pyrolytic graphite). Furthermore, the specific resistivity in the *c*-axis of all samples of pyrolytic graphite was high, about 0·5 ohm cm. These values may be compared with previous direct determinations on very small single crystals[5]. A further test of the absence of serious crystal defects in the specimens now used was the measured temperature coefficient of resistance. With the best samples, this was always positive over the range 80–670° K. in the *a*-axis. In the *c*-axis direction of pyrolytic samples the temperature coefficient of resistance was negative.

It was found that because of the excellent alignment, these specimens could take up adducts such as bromine, iodine monochloride, or potassium, up to the limiting values characteristic of the most highly charged crystal compounds, without cracking due to uneven expansion of individual regions in the specimen. By suitable methods, practically all the adduct could be removed again, with recovery of the specimen. This could be treated in various cycles of crystal compound formation and decomposition while actually mounted in the jig used for resistance measurements.

Changes of conductance now found on forming crystal compounds of graphite can be referred to specific directions in the crystal. For compactness, *relative* changes R(crystal compound) / R(graphite) are recorded in Fig. 1. The values refer to room temperature but the temperature coefficients are small.

It will be seen that formation of the crystal compound leads to a marked decrease of resistance in the *a*-axis direction parallel to the planes of carbon hexagon networks. This accords with the previous interpretation that the conduction bands of the aromatic macro-molecules accept electrons from the potassium, and probably donate electrons to the bromine. However, the use of our highly oriented specimens of graphite permits the further conclusion that in this direction in the crystal the changes for the different crystal compounds are comparable in order of magnitude, with a reduction factor of about 10 in each case (Fig. 1).

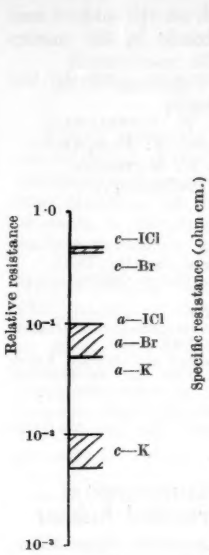

Fig. 1

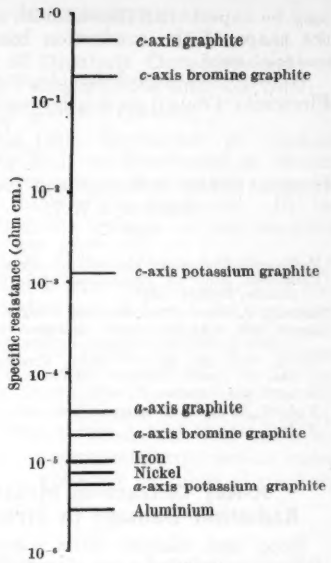

Fig. 2

Fig. 1. Relative change of resistance in *a*- and *c*-axis directions on forming crystal compounds of graphite

Fig. 2. Comparison of resistivity of well-aligned graphite and its crystal compounds with that of some metals

In the direction perpendicular to these networks, the decrease in resistance is even more striking. For the bromine and iodine monochloride adducts, only a small reduction factor (about 2) is observed. For potassium, on the other hand, the reduction factor is about 100–200. This relatively enormous increase in electrical conductance accords well with the view that the potassium atoms form 'quasi-metallic' bonds with the aromatic macromolecules in the crystals; these permit metallic conduction paths in the direction of the *c*-axis as well as those already present in the direction of the *a*-axis. The change to a more positive temperature coefficient lends further support to this view.

Tentatively, the much lower increase in *c*-axis conductance of graphite/bromine may be related with its different crystal structure. In potassium/graphite, C_8K (ref. 6), alkali metal atoms enter every layer and can thus form continuous metallic paths. In graphite/bromine, C_8Br, only alternate layers between the hexagon networks are occupied by the bromine (ref. 7). Thus, conduction paths are separated by a single Van der Waals repulsion distance from one another. This kind of solid conductor is comparatively novel electronically and may prove to exhibit other properties by means of which our tentative interpretation may be tested. For graphite/iodine monochloride it is not yet certain whether the adduct enters every layer or alternate layers[8]. The present resistivity would suggest that the structure is in fact similar to that of bromine/graphite.

It seems worth adding that the increases of conductance with the highly oriented specimens now available make potassium/graphite in the *a*-axis directions rather better than nickel as a conductor of electricity (Fig. 2). Other adduct atoms are being tested to see how far the nature of the adduct affects the increase of metallic conduction attainable; this

may be expected to depend both on the adduct and the shape of the conduction bands in the parent material used.

We wish to acknowledge the support given by the Electricity Council to this research.

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X-Ray Diffraction Measurement of Radiation Damage in Stretched Rubber

Bopp and Sisman[1] have mentioned that X-ray diffraction revealed a loss of crystallinity in a specimen of natural rubber irradiated to 10^7 r. in a reactor while stretched 300 per cent. During a study of radiation damage to elastomers, we have also observed the extreme sensitivity of stretched rubber to radiation.

5/32-in. sections of rubber specimens were stretched 500 per cent, exposed to a high irradiance of 1,000 kVp. X-rays until ruptured and periodically assessed for stress relaxation as manifested by diminished X-ray diffraction intensities.

An experimental mill-mixed rubber was used which was capable of sustaining a high stress without relaxation. Its composition, by weight, was as follows: deproteinized pale crepe, 100; sulphur, 2; zinc oxide, 3; zinc dibutyldithiocarbamate, 0·25; 2-mercaptobenzothiazole, 0·4. It was cured for 20 min. at 138° C. Specimens consisted of strips 10 mils thick and 1·3 in. wide, and were degassed *in vacuo*.

The stretched specimens were held by two Hoffman-type screw clamps mounted on a metal frame. They were firmly fixed by sandwiching between two aluminium plates, 1/16 in. thick, screwed to the frame. An aperture 1 cm. × 1 cm. in the plates exhibited the centres of the specimens for study.

Irradiations were carried out in an atmosphere of nitrogen with the General Electric Co. 'Resotron-1000' operated at 3 m.amp. and 1,000 kVp. Ferrous sulphate dosimetry showed an absorbed dose-rate of $2·4 \times 10^5$ r./hr.

X-ray diffraction patterns were taken with the General Electric Co. *XRD*-3 Geiger-counter spectrometer. Instrumental conditions included a forward reflexion arrangement with the specimen aperture over the goniometer pivot, using copper $K\alpha$ radiation with a 3-deg. beam slit, Soller slit, 0·05-deg. detector slit scanning 2θ at 0·2 deg. per min., and nitrogen currents past both sides of the specimen.

When the specimens were arranged with the direction of stretch horizontal, the Geiger counter scanned the amorphous halo along the X-axis shown in the pre-irradiation pinhole diagram in Fig. 1. With the direction of stretch vertical, the counter scanned the diffraction spots and the halo between them along the Y-axis. An amorphous halo pattern

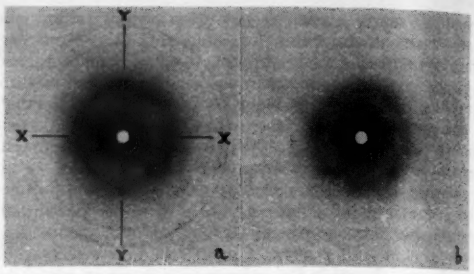

Fig. 1. X-ray diagrams of stretched rubber showing a loss of diffraction intensity upon irradiation: *a*, before irradiation; *b*, after $1·85 \times 10^6$ r. absorbed dose

was obtained by subtracting the spectrometer chart pattern for air-scatter from one for a specimen stretched in the horizontal direction. A diffraction spot pattern was obtained by subtracting a spectrometer chart pattern for a specimen stretched in the horizontal direction from the corresponding one for a vertical direction of stretch. The amorphous halo ran snugly between the diffraction spots of interest (Fig. 1) and added its outer shoulder intensities significantly to the intensities of the diffraction spots. The subtraction removed the influence of the amorphous halo and also the influence of air-scatter, since this was a constant factor. The diffraction spot pattern obtained by the subtraction represents the composite or 'average' of patterns produced by two rectangular areas of specimen, both having dimensions 5 mils × 375 mils and being centred in the sample-holder aperture with the long side vertical, since the defining aperture of the detector slit was vertical and had these dimensions. One specimen area was presented by a horizontal direction of stretch and had its long side perpendicular to the stretch, while the other area was presented by a vertical direction of stretch and had its long side

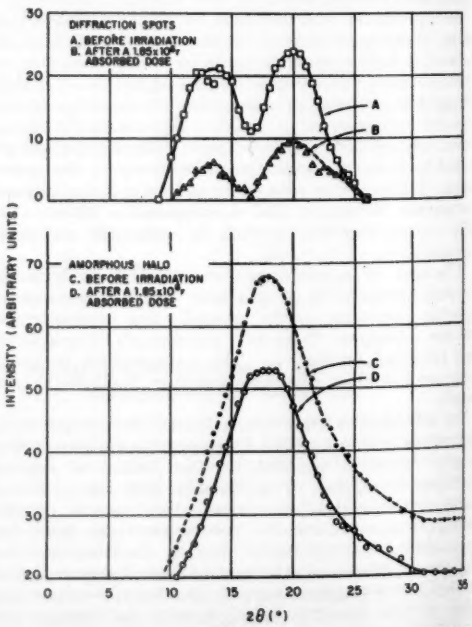

Fig. 2

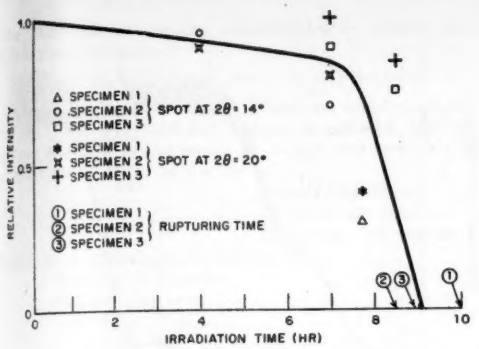

Fig. 3. Decrease in diffraction spot intensity (peak value) versus irradiation-time

parallel to the stretch. The halo intensities of these areas may have differed somewhat, and the diffraction spot pattern obtained by the subtraction is considered to be a semi-quantitative diffraction view of the specimen, useful for following and comparing radiation damage in rubber.

Stretched rubber is extremely sensitive to radiation damage, manifested by stress relaxation with attendant changes in X-ray diffraction intensity (Fig. 1) and early rupture. The average rupturing dose for three specimens was $2 \cdot 2 \times 10^6$ r.

Fig. 2 shows diffraction patterns for spots and halo for a specimen before irradiation and after a nearly rupturing dose of $1 \cdot 85 \times 10^6$ r. The changes suggest specimen thinning and conversion of some crystalline domain to amorphous. Diffraction intensity is extremely sensitive to thickness with very thin specimens of rubber. Hypothetically, if loss in spot intensity were due solely to thinning without any conversion of crystalline to amorphous domain, the spot and halo intensities would be decreased by the same percentage. If additionally an appreciable change from crystalline to amorphous domain occurred, the halo intensity would be reinforced appreciably, and the net result would be a percentage decrease in spot intensity greater than that of the halo. Fig. 2 displays this disparity.

Stress relaxation and attendant loss of diffraction spot intensity were detectable only after a significant lapse of time after initial irradiation. Fig. 3 shows the rate at which the maximum spot intensities decreased, and shows a detectable decrease after about 4 hr., which represents about 50 per cent of the rupturing dose.

It is believed that chain scission dictates the physical–mechanical radiation behaviour of stretched rubber. Stress relaxation would make scissions irreversible and their increase would soon weaken the specimen to the point when the chains slip and rupture of the specimen occurs. Cross-linking undoubtedly occurs simultaneously, but at too slow a rate to prevent destruction of the specimen. The extremely low doses which caused rupture in stretched specimens do not produce detectable physical–mechanical changes in unstretched rubber where cross-linking predominates.

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CHEMISTRY

Behaviour of Dicobalt Octacarbonyl at Elevated Temperature and Carbon Monoxide Pressure

While studying the dissociation of dicobalt octacarbonyl ($Co_2(CO)_8$), we found that at certain pressures and temperatures 1 mole of carbon monoxide was absorbed per mole of the compound. On increasing or lowering the temperature the absorbed carbon monoxide was given off.

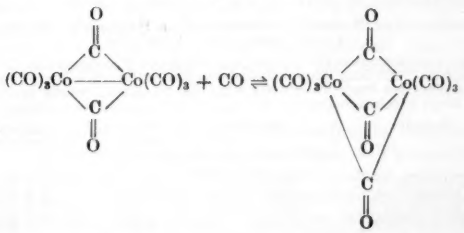
In a typical experiment, an autoclave provided with a heating mantle was charged with 77·4 gm. (226 m.mol.) of dicobalt octacarbonyl, the autoclave was pressured with carbon monoxide to 277·3 atm. at 28° C., and then was slowly heated to a certain temperature. To ensure equilibrium conditions, pressures were recorded only after temperature and pressure had remained constant for several hours. The differences between theoretical and observed pressure at various temperatures, expressed in moles of carbon monoxide absorbed per mole of dicobalt octacarbonyl, are given in Table 1.

Table 1

Moles of carbon monoxide absorbed per mole of dicobalt octacarbonyl	0·496	0·646	0·765	0·918	1·035	0·925
Temperature (° C.)	100	130	145	160	185	210
Observed pressure in atmospheres	342	362	373	378	393	425

The calculations are based on published compressibility data[1] and on the fact that the free space of the autoclave (after addition of dicobalt octacarbonyl) was 167 ml. The calibration of the pressure gauge permitted readings with an accuracy of ± 0·3 atm. After each reading the autoclave was allowed to cool to room temperature and the pressure then was recorded. The amount of carbon monoxide which remained absorbed at 28° C. and 272·2 atm. was found to be 0·095 mole of carbon monoxide per mole of dicobalt octacarbonyl.

It is unlikely, on the basis of molecular orbital considerations, that the uptake of carbon monoxide by dicobalt octacarbonyl is due to the formation of a dicobalt nonacarbonyl complex ($Co_2(CO)_9$):



Such a complex is structurally analogous to, but contains two more electrons than, iron enneacarbonyl ($Fe_2(CO)_9$). These two electrons would have to occupy the antibonding A_{1u} orbital[2] and thereby destabilize the complex.

A more plausible explanation of the uptake of carbon monoxide is to assume dissociation into a carbonyl cation and an anion:

$$CO + Co_2(CO)_8 \rightleftharpoons [Co(CO)_5]^+ + [Co(CO)_4]^-$$

In both ions cobalt has a stable rare-gas configuration. The dissociation of dicobalt octacarbonyl induced by carbon monoxide is entirely analogous to that induced by strong bases (B)[3,4]:

$$B + Co_2(CO)_8 \rightleftharpoons [BCo(CO)_4]^+ + [Co(CO)_4]^-$$

It is possible that other binuclear carbonyls such as manganese decacarbonyl ($Mn_2(CO)_{10}$) will behave similarly:

$$CO + Mn_2(CO)_{10} \rightleftharpoons [Mn(CO)_6]^+ + [Mn(CO)_5]^-$$

This finding may lead to a clearer understanding of the mechanism involved in certain reactions catalysed by metal carbonyls[4,5].

We wish to thank Prof. H. H. Jaffe of the University of Cincinnati for helpful discussions.

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Polarography of Pentacyanocobaltate(III) Complexes

The cobalt(III) complexes of pentacyano-type, $[Co(CN)_5X]$, including several kinds of the new complex compounds, $K_3[Co(CN)_5Cl]$, $K_3[Co(CN)_5SCN]$, $K_3[Co(CN)_5N_3].2H_2O$, $K_3[Co(CN)_5NO_2]$ and $K_4[Co(CN)_5SO_3].2H_2O$, have been studied polarographically. The pentacyano complexes were found to be divisible into two groups from the point of view of their polarographic behaviour. The ions of one group, $[Co(CN_5Cl]^{3-}$, $[Co(CN)_5Br]^{3-}$, $[Co(CN)_5I]^{3-}$ and $[Co(CN)_5SCN]^{3-}$, were reduced irreversibly in two steps to cobalt(I) complexes, through the cobalt(II) state at the dropping mercury electrode in potassium halide supporting electrolyte (Table 1). The ratio of the height of the first wave to that of the second is approximately 1 : 1.

Table 1. The Half-wave Potentials of Halogeno- and Thiocyanato-pentacyano Complexes.

The concentration of the complex ions was 0·005 *F*, temperature, 25° C. The results for the halogeno complexes were obtained in the presence of 0·0032 per cent 'Tween-80', since all the second waves had the small maxima except in the case of the thiocyanato complex

Complex	$E_{1/2}$ of first wave Co(III) → Co(II) (V. vs. S.C.E.)	$E_{1/2}$ of second wave Co(II) → Co(I)	Supporting electrolyte
$K_3[Co(CN)_5Cl]$	−0·86 V.	−1·20 V.	3 *F* KCl
$K_3[Co(CN)_5Br]$	−0·71$_5$	−1·18	3 *F* KBr
$K_3[Co(CN)_5I]$	−0·71	−1·13	3 *F* KI
$K_3[Co(CN)_5SCN]$	−0·78	−1·23$_4$	1 *F* KCl

The ions of the other group, $[Co(CN)_5N_3]^{3-}$, $[Co(CN)_5S_2O_3]^{4-}$, $[Co(CN)_5NO_2]^{3-}$ and $[Co(CN)_5SO_3]^{4-}$, were reduced irreversibly in one step to cobalt(I) complexes (Table 2). The height of the wave for the ions of the latter group is almost equal to the total height of the waves for the ions of the former at the same concentration (Fig. 1).

The currents are completely controlled by diffusion with respect to all the pentacyano complexes. The diffusion current and the concentration of the complex ion are linearly related at the concentration in the range $10^{-3} \sim 5 \times 10^{-4}$ *F* (expressed as the 'formality', namely, the number of gram formula weights per litre of solution—cf. ref. 1).

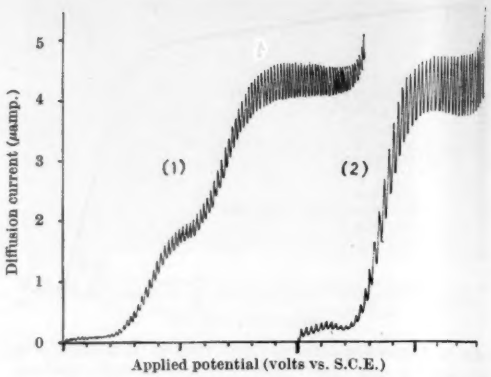

Fig. 1. Typical polarograms of pentacyano complexes obtained at the concentration of 0·001 *F*. Sensitivity: 1 : 80. (1) $[Co(CN)_5Cl]^{3-}$, in the presence of 0·0032 per cent 'Tween-80' (polyoxyethylene sorbitan mono-oleate). Supporting electrolyte: 3 *F* potassium chloride, from −0·5 V. (2) $[Co(CN)_5NO_2]^{3-}$, supporting electrolyte; 1 *F* potassium chloride, from −1·0 V. (versus S.C.E.), 100 mV./absc.

The half-wave potentials of the first waves for the ions of the former group are in the range $-0{\cdot}7 \sim -0{\cdot}9$ V. (versus the saturated calomel electrode), in potassium halide-supporting electrolyte, whereas those of the ions of the latter are in the range $-1{\cdot}2 \sim -1{\cdot}6$ V. (versus the saturated calomel electrode). On the other hand, for most of the usual cobalt(III) complexes, which are reduced to the metal through the cobalt(II) state, for example, ammine complexes, the half-wave potentials of the first waves are in the range +0·7 V. to −0·7 V. (versus the saturated calomel electrode)[2]. Thus the pentacyano complexes are very stable with respect to polarographic reduction. This is considered to be due to the stabilization of the complexes by the strong π-bond character in the bond between cobalt(III) and CN^-, that is to say, the co-ordinating bond is to be expressed by the formula $Co{=}C{=}N^-$ rather than by $Co{-}C{\equiv}N$. Accordingly, the stable existence of the oxidation state, + 1, in the polarographic reduction is not considered to belong only to the pentacyano complexes[3].

The polarographic stability of the pentacyano complexes increases in the following order of the ligand, *X*:

$$Cl^-, Br^-, I^-, SCN^- < N_3^- < S_2O_3^{2-} < NO_2^- < SO_3^{2-} < CN^-$$

As regards the reduction processes of the pentacyano complexes, they are believed to be as follows. For the ions of halogeno- and thiocyanato-complexes:

$$[Co(CN)_5X]^{3-} + e^- \rightarrow [Co(CN)_5X]^{4-} \quad \text{1st step}$$
$$[Co(CN)_5X]^{4-} + e^- \rightarrow Co(I)\ \text{complex} \quad \text{2nd step}$$

Table 2. The Half-wave Potentials of Azido-, Thiosulphato-, Nitro- and Sulphono-pentacyano Cobaltate(III) Complexes. Supporting electrolyte, 1 *F* potassium chloride; temperature, 25° C. The concentration of complex ions was 0·005 *F*.

Complex	$E_{1/2}$ of the wave, Co(III) → Co(I) (V. vs. S.C.E.)
$K_3[Co(CN)_5N_3).2H_2O$	−1·37$_5$*
$K_4[Co(CN)_5S_2O_3]$	−1·29
$K_3[Co(CN)_5NO_2]$	−1·33$_5$
$K_4[Co(CN)_5SO_3].2H_2O$	−1·53$_5$
$K_3[Co(CN)_6]$	No reduction wave

* This result was obtained in the presence of 0·0064 per cent 'Tween-80'. The wave of the ion $[Co(CN)_5N_3]^{3-}$, which precedes that of the ion $[Co(CN)_5S_2O_3]^{4-}$, in the absence of the maximum suppressor, is shifted towards the negative direction of potential due to the presence of the maximum suppressor, 'Tween-80'.

For the ions of azido-, thiosulphato- nitro- and sulphono-complexes:

$$[Co(CN)_5X]^{(2+n)-} + 2e^- \rightarrow Co(I) \text{ complex}$$

The structure and the co-ordination number of the cobalt(I) complex are not known at present, though efforts are now being made to isolate the complex in a solid state from the solution.

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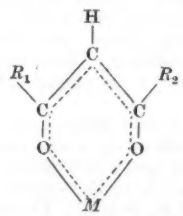
Metal – Oxygen Stretching Frequencies in the Metal Chelate Compounds of β-Diketones

RECENTLY, many papers[1] have been published on the infra-red spectra of metal chelate compounds of β-diketones in the sodium chloride (4,000 ~ 650 cm.$^{-1}$) region. The empirical assignments of the observed bands have also been made by Lecomte and other workers[2]. Since the CO stretching bands can be identified without much ambiguity, attempts have been made to correlate their frequencies with the stability of the chelates[3] or the ionization potential[4] of various metals.

It is expected, however, that the metal – oxygen stretching frequencies of these compounds are chemically most interesting since they are closely related to the stabilities of the chelates. Unfortunately, they are difficult to identify because they appear outside the sodium chloride region, and, furthermore, strong coupling with other modes may be involved.

We measured the spectra of thirty-two compounds of the following type in the 1,700 ~ 280 cm.$^{-1}$ region using optical components of sodium chloride, potassium bromide and cæsium bromide:



where, R_1, R_2 and M are variables. It was found that, in acetylacetonates and benzoylacetonates, the bands, ranging from 420 to 480 cm.$^{-1}$, shift to higher frequencies and increase in intensity as the metal is changed in the order (of stability): $Co^{2+} < Ni^{2+} < Cu^{2+} < Pd^{2+}$, as is shown in Table 1.

Table 1

	Acetylacetonates	Benzoylacetonates
Co^{2+}	420 cm.$^{-1}$	423 cm.$^{-1}$
Ni^{2+}	453	452
Cu^{2+}	455	458
Pd^{2+}	466	478
Al^{3+}	490	470

Also, in Cu^{2+} or Ni^{2+} chelates of various β-diketones, the same band shifts to higher frequency as R_1 and R_2 are changed in the order (of stability): CF_3, $CF_3 < CF_3$, $CH_3 < CH_3$, $CH_3 < C_6H_5$, $CH_3 < C_6H_5$, C_6H_5, as is shown in Table 2.

Table 2

R_1,	R_2	Cu^{2+}	Ni^{2+}
CF_3,	CF_3	—	—
CF_3,	CH_3	445	427
CH_3,	CH_3	455	453
C_6H_5,	CH_3	458	453
C_6H_5,	C_6H_5	463	460

These results seem to suggest that this band may be due to one of the metal – oxygen stretching modes or is at least closely related to it. In order to confirm this and to determine the coupling nature of this band, the normal co-ordinate treatment is necessary and will be carried out.

We wish to thank Prof. R. C. Lord, jun., of the Massachusetts Institute of Technology, for aid in obtaining the spectra in the cæsium – bromine region.

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Existence of Two Liquid Phases in the System Cobalt Chloride–Water–Acetone

Katzin and Ferraro[1] have examined the composition of the solid phases and their equilibrium solutions in the system cobalt chloride–water–acetone at 25° C. During further studies of solutions containing these components it has been noticed that for certain water–acetone mixtures the addition of cobalt chloride can lead to a separation of two liquid phases.

Fig. 1 gives the relation of the region of immiscibility to the phase diagram given in ref. 1. The results were obtained by titrating aqueous cobalt chloride solutions, made from the recrystallized 'Analar' hexahydrate, with 'Analar' acetone, weighing both the portion of aqueous solution and the final mixture with acetone. A few points were obtained by preparing saturated solutions of the salt in known water–acetone mixtures, and titrating these with acetone or with water–acetone mixtures. The points in the present work were obtained at room temperatures of 20–21° C., whereas the saturation curve was determined at 25° C. A tie-line running through the centre of the immiscible region is also included in the phase diagram. It was obtained by analysing the two phases for cobalt and for water (by a Karl Fisher titration).

The immiscible area follows the saturation curve fairly closely, but a number of experiments have shown that at 25° C. there is a single liquid phase

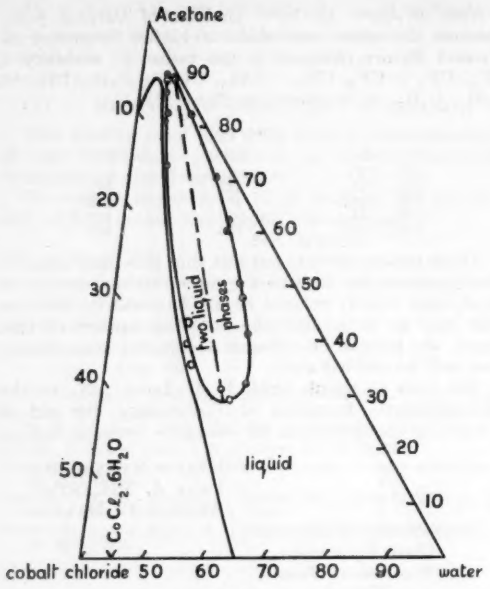

Fig. 1

at saturation. However, cooling to 20° C. may give two liquid phases in equilibrium with solid phase for solvent mixtures containing about 55 weight-per cent water, 45 per cent acetone. Single-liquid phases exclusively occur with compositions containing more than 90 per cent or less than 28 per cent acetone, and for mixtures containing less than 1 per cent of cobaltous chloride. It is interesting, as a phenomenon, that the addition of increasing amounts of cobalt chloride to a portion of, say, 50–50 water and acetone gives simple solution for a considerable concentration range; then there occurs a limited composition region in which there are two liquid phases, finally again a single liquid which remains so to saturation with solid. If the initial solvent mixture contains about 33 per cent acetone, the region of separation might appear as a minute region of turbidity only.

From the effect of temperature on some mixtures of fixed composition in sealed tubes it has been observed that the immiscible region expands as the temperature is raised. This expansion is most noticeable in the region of highest water concentrations, so that on raising the temperature we need progressively less acetone to produce a phase separation from a given cobalt chloride–water solution. The upper part of the immiscible region does not appear to be very sensitive to temperature changes.

For an over-all composition corresponding to a point near the middle of the region of phase separation, the phase rich in acetone is a light blue ($\lambda_{max.} \sim$ 672 mμ) and the phase rich in water is a deep magenta with two main regions of absorption ($\lambda_{max.} \sim$ 515 mμ, 664 mμ). These spectra correspond respectively to those for tetrahedrally co-ordinated $CoCl_2.2X$ (where X is a solvent molecule, in this case either water or acetone), and a mixture of this form with the octahedral species $Co(H_2O)_6^{2+}$, $CoCl_2.4X$, and intermediate stages.

It may be inferred that the presence of the two co-ordination states of the cobalt salt, with co-ordination four and six respectively, furnishes a mechanism for formation of two phases of different composition but with activities of the components equal. That is, the separation depends on the apparent fact that the tetrahedral form is preferentially soluble in the phase rich in acetone. The dependence of the phase separation on temperature can be understood since the equilibrium between octahedrally and tetrahedrally co-ordinated cobalt is known to move towards the tetrahedral form on raising the temperature. Other systems in which phases rich in acetone and in water are separated occur, for example, with salts such as potassium chloride and potassium fluoride, which are very soluble in the water and essentially completely insoluble in the acetone[3].

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Rapid Quantitative Horizontal Paper Chromatography at an Elevated Temperature: Determination of Aspartic and Glutamic Acids

By the use of rectangular strips of filter paper, rather than filter paper disks, in combination with a horizontal solvent flow at an elevated temperature, amino-acids are rapidly separated as round compact spots rather than circular bands[1]. This is desirable since such spots in many cases lend themselves to quantitative study by the maximum colour-density technique. Recently, such a procedure has been applied to the analysis of tryptophan in an alkaline hydrolysate of α-casein[2].

This communication presents additional evidence to show that horizontal paper chromatography at an elevated temperature can be made quantitative by the maximum colour-density technique. A method is presented for the determination of aspartic and glutamic acids by direct photometry on paper chromatograms following two one-hour solvent developments at 60° C. in phenol saturated with *p*H 12·0 buffer[1].

For the glutamic acid assay, four standard amino-acid solutions (*p*H 6·5) containing, respectively, 0·100, 0·075, 0·050, and 0·025 μgm. of amino nitrogen are applied alternately to the paper in 0·5 μl. volumes at K_1, K_2, K_3, and K_4 (Fig. 1). The unknown solution is spotted at three concentrations (in 0·5-μl. volumes) to fall within the range 0·025–0·100 μgm. of the standard solutions. The aspartic acid analysis requires four standards in the range 0·075–0·150 μgm.

After colour development of the chromatogram[1], the maximum densities of the amino-acid spots are measured with a Denischron transmission densitometer (Model 3835*B*, W. M. Welch Scientific Company, Chicago, Ill.) using an aperture 1-mm. in diameter and the green filter built into the instrument. A standard curve is prepared by plotting the logarithm of the known concentrations against the densities.

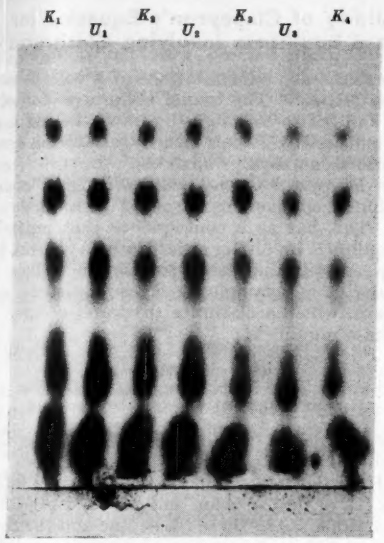

Fig. 1. A quantitative horizontal paper chromatogram of aspartic and glutamic acids after two 1-hr. solvent developments[1] at 60° C. in phenol saturated with *p*H 12·0 buffer

Three 125-mgm. samples of an α-casein preparation[2] were hydrolysed for 24 hr. under reflux in 25 ml. solutions of 6 *N* hydrochloric acid. Following clarification of the hydrolysates as described previously[3], the dried residues were dissolved in 10 per cent *iso*propanol, filtered, adjusted to *p*H 6·5, and made up to a final volume of 25 ml. with 10 per cent *iso*propanol.

The determination of the content of aspartic and glutamic acids in α-casein gave values of 7·84 mgm. per 100 mgm. protein for aspartic acid and 20·43 mgm. for glutamic acid (Table 1). These values were in good agreement with 7·70 mgm. for aspartic acid and 21·02 mgm. for glutamic acid obtained using descending paper chromatography[4].

The accuracy and precision of the method was established by determining the aspartic and glutamic acid contents of a solution containing 40 mgm. of each of 18 common amino-acids per 100 ml. total volume, *p*H 6·5. A value of 39·0 mgm. (2·5 per cent deviation from the true value) was obtained for aspartic acid (Table 2) and 39·6 mgm. (1·0 per cent deviation) for glutamic acid. These values compared well with the values of 40·5 mgm. and 40·7 mgm. obtained for aspartic and glutamic acids using descending paper chromatography[5].

Table 1. The Aspartic and Glutamic Acid Content of α-Casein as Determined by Horizontal Paper Chromatography

Chromatogram	Concentration found (mgm./100 mgm. α-casein) Aspartic acid	Glutamic acid
1	7·83	19·99
2	7·64	20·65
3	8·04	20·65
Average	7·84	20·43
Standard deviation	0·20	0·38
Descending paper chromatography (ref. 4)	7·70	21·02

Table 2. Accuracy and Precision of the Horizontal Paper Chromatographic Determination of Aspartic and Glutamic Acids

Chromatogram	Concentration found (mgm./100 ml.) Aspartic acid	Glutamic acid
1	39·9	39·9
2	38·0	41·0
3	39·0	37·8
Average	39·0	39·6
Standard deviation	0·95	1·63
Deviation from theoretical value, 40 mgm./100 ml., per cent	2·5	1·0

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A New Sensitive Indicator for Semi-Micro Chelometric Titrations

Recently, a new colorimetric reagent was introduced for the spectrophotometric determination of magnesium[1]. This reagent (LaMotte Chemical Products Co., Chestertown, Md.), 1-azo-2-hydroxy-3-(2.4-dimethylcarboxanilido)-naphthalene-1′-(2-hydroxybenzene), given the trivial name 'magon', has now been found to be useful as an indicator in the direct titrimetric determination of small amounts of magnesium.

There are several direct photometric methods for the determination of magnesium, of which titan yellow[2] and eriochrome black *T*[3] are examples. There is need for a direct titrimetric procedure for magnesium. Chelometric titrations employing ethylenediamine tetraacetate are widespread. These methods, as utilized for the determination of calcium and magnesium, include a titration of calcium and magnesium using eriochrome black *T* and a titration of calcium alone using murexide[4], zinchrome *R*[5], calcon[6] or other indicators. By the ethylenediamine tetraacetate method, magnesium is determined by difference between the two titrations. Errors encountered in either or both titrations affect the validity of the magnesium value. A direct value would be an improvement for the accurate titrimetric determination of small amounts of magnesium in the presence of large amounts of calcium.

This communication presents results of direct titrations of magnesium using the new, sensitive indicator magon. The indicator forms a coloured complex with small amounts of magnesium but not with small amounts of calcium. Magnesium in the complex is removed by titrating with ethylenediamine tetraacetate, resulting in a sharp colour-change of yellow-red to blue-violet to blue. The blue end-point is slower than the blue-violet but either colour-change can be used.

The results (Table 1) demonstrate that this indicator can be used in determining μgm. amounts of magnesium, recovery values being satisfactory. Metals such as copper and iron interfere by affecting the sharpness of the end-point. This difficulty may be alleviated by adding a small amount of solid potassium cyanide to the solution before adding the magon. The addition of a small amount of cyanide to the

Table 1. Direct Titrimetric Determination of Magnesium in Synthetic Solutions

Mgm. present γ	Ion added γ	Mgm. found* γ	Difference γ
5	—	5	0
5	—	6	1
10	—	10	0
10	—	9	1
25	—	23	2
25	—	23	2
50	—	49	1
50	—	50	0
100	—	99	1
100	—	100	0
50	Cu-25	56†	6
50	Cu-25	50‡	0
50	Cu-50	50‡	0
50	Cu-50	50‡	0
100	Fe-50	100‡	0
100	Fe-100	98‡	2
100	Fe-100	98§	2

* Procedure includes 10 ml. Clark and Lub's buffer *p*H 9·0, plus 15 ml. absolute methanol, plus 10 ml. magon (0·10 mgm./ml. MeOH). The solution is adjusted, if necessary, to *p*H 10·5 and then titrated with 0·005 *N* ethylenediamine tetraacetate.
† End-point fades, no cyanide present.
‡ 1–3 mgm. potassium cyanide added prior to addition of magon.
§ 1–3 mgm. ascorbic acid added prior to potassium cyanide.

solution should be made since large amounts slightly decrease the sensitivity of the colour-change. A buffer system, ammonium hydroxide–ammonium chloride, was unsatisfactory because of decreased sensitivity of the end point. Borate and tetraborate appear to increase a sharp colour change. Magon, essentially insoluble in water, is soluble in ethanol and methanol. Therefore the compound is dissolved in methanol and more methanol is added to the solution to be titrated. The concentration of alcohol in the solution to be titrated should range between 30 and 80 per cent. The indicator should be made fresh daily. Methanol is preferred since some decreased end-point sensitivity is encountered when using 95 per cent ethanol.

For this titration a *p*H-range of 9·0–11·0 is necessary. Clearest colour-changes are from *p*H 10·0 to 10·5. In the standardization of ethylenediamine tetraacetate with magnesium, the *p*H should be adjusted accurately to a selected *p*H within 10·0–10·5 and this same *p*H maintained for all titrations with the standardized titrant.

Under the above conditions the titration can be used for determining the combined amounts of calcium and magnesium, since calcium is titrated before magnesium. Calcium may be separated from magnesium as the precipitated calcium tungstate[7]. Preliminary results in this laboratory show magon to be very sensitive for the determination of total hardness of waters.

The possible usefulness of this new, sensitive indicator, or its magnesium complex, in the titration of micro-amounts of other metals should not be overlooked[8].

I wish to acknowledge the technical assistance of Neil Scott McNutt.

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Validity of Clapeyron's Equation for Phase Equilibria involving Clathrates

Clathrates are solid solutions of a volatile solute in a host lattice[1]. The quinol clathrates studied by Powell[2] and the so-called gas hydrates[3] belong to this class of substances. Their host lattices, when empty, are thermodynamically unstable. In this respect they are different from the zeolites (Barrer[4]) in which the occluded component is sorbed in a stable host lattice. This has as a consequence that univariant phase equilibria involving a clathrate, in general, have no counterpart in the case of sorption in zeolites.

Consider, for example, a binary system water plus gas in which a clathrate (hydrate) occurs. The three-phase equilibria:

$$\text{ice} - \text{clathrate} - \text{gas} \qquad (1)$$

and

$$\text{aqueous solution} - \text{clathrate} - \text{gas} \qquad (2)$$

then are univariant ones in which the composition of the clathrate varies along the three-phase lines. The heat ΔH of decomposition of the clathrate into ice and gas (1), or into solution and gas (2), can be found from the slope of the three-phase line and the change in volume ΔV, according to Clapeyron's equation:

$$\frac{dP}{dT} = \frac{\Delta H}{T\Delta V} \qquad (3)$$

The values of ΔH per mole of solute thus obtained by earlier investigators and quoted by von Stackelberg[3] and Barrer and Stuart[5] are not invalidated by the fact that hydrates are solid solutions instead of stoicheiometric compounds. Equation (3) is a direct consequence of the second law of thermodynamics, and as such exact for all univariant equilibria, irrespective of the number of components.

Quite separate from Clapeyron's equation, one has a relation which determines the change in composition of the clathrate solution necessary to maintain equilibrium with ice in (1), or with an aqueous liquid in (2), when temperature or pressure are varied (compare, for example, equation (3.12) of ref. 1*a* and equation (15) of ref. 5). The latter relation is completely analogous to the well-known formula for the depression of the freezing point of ideal liquid solutions.

Clearly, equilibrium (1) is not analogous to the sorption equilibrium of a gas in a zeolite. The latter is a bivariant equilibrium to which Clapeyron's equation is not applicable, and for which the heat of desorption is proportional to the derivative $(\partial P/\partial T)$ at constant sorbed excess number of moles (cf. ref. 6, pp. 201–205, for an elegant treatment of this problem).

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THERE is a difficulty which can occur regarding the interpretation of heats derived from Clapeyron's equation applied to phase equilibria involving clathrates. This difficulty is not thermodynamic in origin but arises from the non-stoicheiometry of the phases. Before this non-stoicheiometry was realized, heats evaluated using Clapeyron's equation were considered to refer to fully stoicheiometric reactions, for example :

$$CHCl_3 + 17H_2O \rightarrow CHCl_3.17H_2O \qquad (1)$$

the values 1 and 17 here being regarded as fixed integers. However, equation 1 should be formulated as :

$$xCHCl_3 + 17H_2O \rightarrow xCHCl_3.17H_2O \qquad (2)$$

where x is less than 1, has not a fixed value but may vary with P and T, was unknown to earlier experimenters and indeed in this and many analogous systems is still unknown. x could vary from one experimenter to another according to the physical conditions employed. The heats derived have therefore referred to uncompleted reaction equations and so have an uncertain meaning[1], until x is determined at the same time as the heat of reaction. Fortunately, x in many cases does not differ greatly from an integer, so that uncertainties resulting from non-stoicheiometry are not large.

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BIOCHEMISTRY, PHYSIOLOGY and MEDICAL SCIENCES

Glucuronide and Sulphate Conjugation *in vivo* and *in vitro*

EARLY studies[1] of the metabolism of the polycyclic hydrocarbon 3 : 4 benzypyrene showed that this compound was converted within mouse and rat tissues to one or other of two water-soluble derivatives. These were characterized physically, but not chemically identified, and for convenience in later work were labelled as BpX_1 and BpX_2.

Later, Calcutt and Payne[2] showed that within mouse or rat liver—the major site of benzpyrene metabolism—BpX_1 was formed only in association with the heavy components of the soluble proteins representing the supernatant fraction of cell homogenates. On the other hand, BpX_2 was formed in the nuclei, mitochondria, microsomes and lighter components of the supernatant. The major site of formation of this derivative was the microsomes[3].

Harper[4] has now obtained evidence that BpX_1 is a mixture of the sulphuric acid conjugates of fully aromatic benzpyrenols, while BpX_2 is a mixture of the glucuronic acid conjugates of the same phenols.

It now becomes possible to correlate the above results concerning the primary metabolism of benzpyrene with other information in the literature dealing with *in vitro* systems of conjugation. It has been shown by Bernstein and McGilvery[5] and De Meio *et al.*[6] that sulphate conjugation *in vitro* is based upon an enzyme system present in the high-speed fraction of the supernatant from liver homogenate. Activity is dependent upon the presence of adenosine triphosphate and magnesium ions. The identification of the benzpyrene X_1 derivative as a mixture of sulphuric acid esters now gives an example of correspondence between *in vivo* and *in vitro* conjugation systems. In both cases sulphate conjugation has been found to be associated with the same cellular sub-fraction.

In the case of glucuronide synthesis *in vitro* activity has been found in the microsome fraction of liver homogenate[7,8] and to a lesser extent in nuclei and mitochondria[9]. With the recent proof that benzpyrene X_2 is a mixture of glucuronic acid conjugates we again have an exact parallel between *in vivo* and *in vitro* behaviour. In this case the parallel is not only with regard to the cellular sub-fractions concerned but also with the relative amounts of conjugate formed.

So far as we are aware this evidence, based on work with 3 : 4 benzpyrene, is the first example of known *in vitro* systems for glucuronic and sulphuric acid conjugation proving to be an accurate reflexion of behaviour in whole tissues under *in vivo* conditions. Furthermore, it is also apparent that the processes of homogenization and ultracentrifugation involved in the extraction of these enzyme systems for *in vitro* use do not result in the loss or redistribution of these systems.

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Conjugated Forms of Urobilinoid Pigments

TAKASHI NORO[1] reported a fraction of urinary urobilinoids not extractable with chloroform but extractable by saponification with potash; this fraction he assumed to be in the ester form of the urobilinoids. We have found that some of the urinary urobilinoids not extractable with chloroform are characterized by their adherence to the gel-like precipitate formed during the extraction. Shaking normal urines, or preferably those from cases of hæmolytic jaundice, with Sevag's chloroform–amyl alcohol (9 : 1) mixture[2] results in partition of their urobilinoid contents. After centrifugation, part of the urobilinoids are found bound to the precipitate which collects at the interface and are extractable from it with ethyl acetate but not with chloroform, while the other part passes into the chloroform – amyl alcohol phase.

The paper chromatographic behaviour of these fractions was different. (Solvent : chloroform saturated with water–butanol–pyridine saturated with water (2·2 : 1·8 : 1); the urobilinoids were visualized by their green fluorescence in ultra-violet light after spraying with Schlesinger reagent.) The fraction

extracted with chloroform migrated with the solvent front, but the bound urobilinoids behaved as a mixture of at least two compounds, the first of these remained at the start line, while the second moved slowly as an oblong spot behind the front. The first spot was readily stainable with protein dyes (for example, acid fuchsin) and by mucopolysaccharide staining procedures[2–5], thus showing its mucoprotein-bound character; the second spot was faintly stained by the latter procedure, and coloured brown by aniline hydrogen phthalate reagent[6] after heating, but was unstained by protein dyes, in accordance with the assumption that it is an oligo- (or mono-) saccharide-conjugated compound. The spot migrating with the front remained unstained by either procedure, which proved that it was free urobilinoid.

The mucoprotein-bound urobilinoids may be prepared separately from the oligo- (mono-) saccharide-conjugated urobilinoids by centrifugation of (*a*) the gel-like precipitate formed by extracting urines with ethyl acetate, or (*b*) of urines saturated with ammonium sulphate after adding 1·5 per cent butanol. This latter method (suggested by Heikel[7] for the preparation of directly reacting bilirubin from urine) yielded bound urobilinoid most abundantly. The mucoprotein-bound moiety can be lifted as a reddish-brown pellicle from the top of the aqueous phase; the oligo- (mono-) saccharide-conjugated urobilinoids pass into the ethyl acetate or butanol supernatant, respectively. The mucoprotein-bound urobilinoids seemed to behave, however, as a source of the oligo- (mono-) saccharide-conjugated pigments, which split off after incubation for 1 hr. at 37° C.; this decomposition was inhibited by 250 μgm./ml. heparin, but enhanced by 2 mgm./ml. trypsin. This splitting from mucoproteins occurred also during paper electrophoresis in Michaelis barbital buffer solution, *p*H 8·6, the oligo- (mono-) saccharide-linked urobilinoids leaving the mucoproteins and moving towards the anode-like free urobilinoids[8].

During electrophoresis in borate buffer (*p*H 8·6; 0·2 *M* H_3BO_3; 0·05 *M* $Na_2B_4O_7$), however, the oligo- (mono-) saccharide-conjugated and free urobilinoids behaved differently. Under these conditions carbohydrates have characteristic mobilities due to the formation of borate complexes, for example, glycuronic acid migrates 1·4 times as fast as dextrose[9]. Borate buffer electrophoresis of the supernatant formed after butanol has been added to urines precipitated by saturation with ammonium sulphate and centrifuged gave three urobilinoid bands, the fastest zone moving 1·4 times faster than dextrose. This zone and the middle one were coloured brown by spraying with aniline hydrogen phthalate and heating. The slowest zone behaved like free crystalline sterkobilin, and both were unstained by aniline hydrogen phthalate. The bands were cut out, extracted separately with the borate buffer described above, and the extracts were tested by Dische's carbazol reaction[10]. The fastest zone proved to contain glycuronic acid, while the slowest one did not.

Gray[11] expected work to be done on the conjugated urobilinoid pigments in urine; the above observations favour the assumption that besides free urobilinoids, urobilinoid glycuronide and another sugar-linked form, at present under investigation, may exist. Possibly these split from mucoprotein-urobilinoid compounds. These forms of urobilinoids were found to be more resistant to oxidation and decomposition during electrophoresis than free urobilinoids[12].

We are indebted to Prof. C. J. Watson for his gift of crystalline sterkobilin used in these experiments.

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Patterns in the Amino-Acid Sequences of the Corticotropins

The complete amino-acid sequences of pig and sheep adrenocorticotropic hormone have been elucidated[1–3]. They have almost identical structures showing only minor variations in the C-terminal region. A striking similarity in pattern occurs in the acidic and basic portions of these proteins, although these regions are comprised for the most part of different amino-acids. This pattern becomes obvious when the amino-acid sequence 24–35 of the acidic portion is listed directly beneath sequence 12–23 of the basic portion. The actual sequences for amino-acids 12–35 are shown in Table 1*a* and *b* for the two proteins. Table 1*d* is a hypothetical sequence compiled from the best pattern correspondence in both. The other portions of both corticotropins, sequences 1–11 and 35–39, are identical.

Table 1. Amino-acid Sequences of Sheep and Pig Adrenocorticotropic Hormone

(*a*) Sheep α-corticotropin (ref. 3)

—pro—val—gly—lys—lys—arg—arg—pro—val—lys—val—tyr—
pro—ala—gly—glu—asp—asp—glu—ala—ser—glu—ala—phe—

(*b*) Pig β-corticotropin (refs. 1 and 2)

—pro—val—gly—lys—lys—arg—arg—pro—val—lys—val—tyr—
pro—asp—gly—ala—glu—asp—glu—leu—ala—glu—ala—phe—

(*c*) Pig corticotropin-*A* (ref. 4)

—pro—val—gly—lys—lys—arg—arg—pro—val—lys—val—tyr—
—pro—gly—ala—glu—asp—asp—glu—leu—ala—glu—ala—phe—

(*d*) Hypothetical sequence

12 13 14 15 16 17 18 19 20 21 22 23
—pro—val—gly—lys—lys—arg—arg—pro—val—lys—val—tyr—
pro—ala—gly—glu—asp—asp—glu—leu—ala—glu—ala—phe—
—ser—
24 25 26 27 28 29 30 31 32 33 34 35

In the hypothetical sequence proline occurs at positions 12 and 24, glycine at positions 14 and 26, and aromatic amino-acids at positions 23 and 35. There is no correspondence at positions 19 and 31. The acidic amino-acids in the bottom chain are found in positions corresponding to those occupied by the

basic amino-acids in the top chain, although there is no correlation between any one of the acidic (glutamic or aspartic) with any one of the basic (lysine or arginine) amino-acids. Similarly, valine on the top chain is replaced by alanine on the bottom. Each of the corticotropins differs from this hypothetical correspondence in pattern by a switch in the positions of two amino-acids in the acidic portion. In pig β-corticotropin, alanine exchanges position with aspartic, and in sheep α-corticotropin, alanine switches with serine. White and Landmann[4] have proposed a slightly different sequence (corticotropin-*A*) for the acidic portion of pig hormone that deviates from the hypothetical sequence only in that alanine in position 25 switches with glycine in position 26 (Table 1*c*).

The repetition of the pattern in the two regions suggests a duplication of the information template that confers the specificity. On a strict gene-template hypothesis having each amino-acid independently specified by a restricted region of the template, a remarkable series of mutations is required in the duplicate region such that the overall pattern is maintained but different amino-acids are specified. I prefer a scheme postulating two levels of information[5], one designating the pattern and the other determining which amino-acids will be incorporated into the pattern. Much of the biological specificity may reside in the pattern rather than in the individual amino-acids, since it has been shown that many major changes can be made in the chemical structure of peptides without affecting their biological specificity[6].

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Distinction between Sodium and Potassium in Change in Permeability effected by Lipid-soluble Analogues of Acetylcholine

B. C. Abbott, A. V. Hill and J. V. Howarth have recently found that a rather strong positive heat roughly coinciding with the active phase follows within 100–300 msec. by a marked negative heat[1]. These results make untenable the assumption of a purely physical process underlying the bioelectric currents during nerve activity as proposed by Hodgkin and his associates. Further support for the necessity of a chemical reaction are the observations of Schoffeniels[2] with the isolated single electroplax of *Electrophorus electricus*: he found a Q_{10} of 3·6 for the action potential; the activation energy is 21,000 cal./mole.

A theory postulating a chemical reaction to be responsible for the change in permeability during conduction was suggested by Nachmansohn fifteen years ago. He proposed that the action of acetylcholine is an intracellular (or intramembranous) process essential for the generation of bioelectric currents. This view is based on a variety of physiological and biochemical features of the acetylcholine system which has the prerequisites for the postulated function, and on its relationships with electrical activity[3].

One of the principal objections to Nachmansohn's theory was the failure of acetylcholine to affect conduction when applied externally. This lack of effect has been explained by the failure of acetylcholine to reach the active sites, since it has been demonstrated that the ester does not penetrate to the inside of the cell[4,5]. Recently, however, a number of lipid-soluble analogues of acetylcholine were prepared. These compounds depolarize the axon in low concentrations and produce muscular contraction by direct action on the conducting membrane. The effects are rapid and, under appropriate conditions, reversible. In still unpublished experiments on isolated nodes of Ranvier, Staempfli and Dettbarn obtained depolarization with 10^{-6} *M* concentration (equivalent to 0·2 μgm. of acetylcholine per ml.). The question naturally occurs about the specific nature of this effect. Evidence in favour of a reaction with the acetylcholine receptor was obtained in experiments with eserine in which antagonistic actions between the alkaloid and the quaternary ammonium ion were found and their competitive nature was demonstrated[6,7].

The problem arises whether the lipid-soluble quaternary ammonium ions change the permeability in a way consistent with the assumption that their action opens the barrier specifically for Na^+, as postulated for acetylcholine, or whether the compounds produce an indiscriminate increase in permeability. This question is important since during activity Na^+ conductance specifically increases several hundred-fold; increase in K^+ conductance follows later and is relatively small. This question has been tested in the following way.

Desheathed tibialis nerve fibres of *Rana pipiens* were exposed to Ringer's solution containing the following lipid-soluble quaternary ammonium ions: noracetylcholine 12 and pyridinium dodecyl iodide (in 10^{-4} *M*) and pyridine aldoxime dodecyl iodide (in 10^{-5} *M*). At these concentrations no effect on the resting potential was observed. When the K^+ concentration in these solutions was raised to 20 m*M*, the depolarization which is usually observed was significantly reduced (about 20 per cent) both in respect to strength and in respect to speed of the response. In all experiments the response to the same K^+ concentration was tested prior to the addition of the quaternary ammonium ions. The results indicate a small but definite decrease of permeability to potassium.

The change to Na^+ permeability effected by these compounds was tested with concentrations five times as high, at which there is a pronounced depolarizing effect in normal Ringer's solution. When Na^+ was replaced by choline chloride, the depolarization was strongly reduced (by 30–50 per cent). On replacing again choline by Na^+, the original strength of depolarization was restored. Thus, the depolarization appears to be effected by a marked increase of permeability to Na^+. The selective change of permeability; small although significant decrease to K^+, marked increase for Na^+, appears pertinent in connexion with the assumption that the lipid-soluble analogues of acetylcholine mimic the physiological action postulated for the ester.

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Depression in Percentage of Milk Fat by Parenteral Glucose Infusion and Glycerol Feeding

Low roughage – high concentrate diets can profoundly depress the fat content of milk[1–6]. One of us has advanced the hypothesis[6] that such depressions are the result of metabolic effects of an increase in the proportion of glycogenic to non-glycogenic products of digestion on such diets. Such an increase could be effected by a proportion of the starch escaping ruminal digestion, high ruminal lactic acid production, and an increased proportion of the glycogenic propionic acid in the products of ruminal digestion. There is evidence that low roughage – high concentrate diets have such effects[5,7,8]. It is also known that the proportions of fat and carbohydrate in the diet of animals can profoundly affect their carbohydrate and lipid metabolism, and changes, although erratic, in blood lipids have been recorded on low roughage diets[5,9], indicating some disturbance of lipid metabolism.

Experiments supporting the above hypothesis are now reported. Cows on normal hay concentrate diets giving milk with normal milk fat percentage were given continuous intravenous infusions of glucose over 48 hr. at the rate of 2 kgm. per 24 hr. and the fat percentage of the milk produced before, during and after the infusion determined. Oxytocin injections were used for obtaining as complete as possible evacuation of the udder at each milking. Normal feed consumption continued during the experiments. Results of a typical experiment are recorded in Fig. 1. Rate of milk production was maintained at quite a constant level during the infusion but fat percentage was rapidly depressed. Similar results were obtained when the concentrate allowance was decreased by an amount calculated to supply the same amount of net energy as the infused glucose.

Glycerol feeding, which would result in an increased proportion of glycogenic to non-glycogenic products of digestion due to high propionic acid production[10], was also found to depress milk fat percentage (Table 1) in agreement with the hypothesis. The glycerol was added to normal hay – concentrate diets, replacing an amount of concentrates calculated to supply the same amount of net energy.

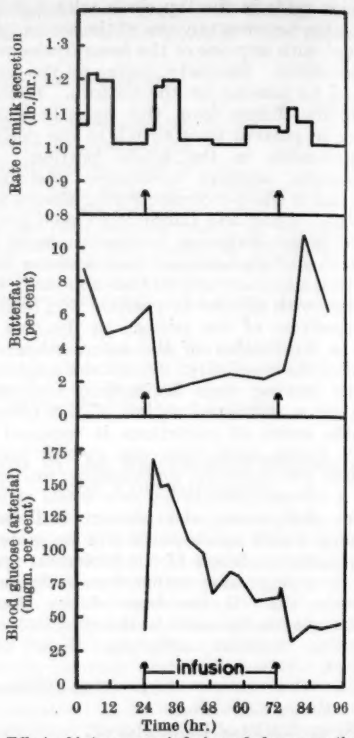

Fig. 1. Effect of intravenous infusion of glucose on the rate of secretion of milk, the butterfat test, and the level of blood glucose in a Jersey cow

It has been suggested that the fall in percentage of fat on low roughage – high concentrate diets is caused by lack of supply of acetate to the mammary gland, and acetate feeding has been reported to return depressed fat percentages to normal[3,4,11]. However, it has been shown that volatile fatty-acid levels in the blood and uptake by the mammary gland are not noticeably reduced on such diets[4]. Although it has yet to be demonstrated that the volatile acid in the blood is predominantly acetic as it is on normal diets[12], it seems likely that the positive results from acetate feeding are due to restoration of a more normal proportion of glycogenic to non-glycogenic products of digestion rather than to remedying an absolute lack of acetate.

Studies on the effect of the glucose infusions on blood lipid fractions are now in progress.

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Table 1. Effect of Glycerol Feeding (6 lb./cow/day) on Butterfat Content of Milk

	Pre-treatment period (13 days)	Glycerol feeding period (days 1–3)	Glycerol feeding period (days 3–13)	Post-treatment period (13 days)
Mean milk production (lb./cow/day)	26·6	26·4	24·8	22·3
Mean butterfat (per cent)				
Cow 1	4·76	4·14	3·81	4·63
Cow 2	5·32	4·87	4·55	5·85
Cow 3	4·68	4·53	3·42	4·94
Mean	4·85	4·42	3·82	5·00
Depression (per cent)		−10·16	−22·36	

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Changes in the Secretion of 20α-Hydroxypregn-4-en-3-one by the Adrenal Gland of Young Calves

In a previous communication[1], we described the isolation of progesterone from the adrenal venous blood of cattle. During the course of this work it was observed that progesterone was sometimes accompanied by a more polar α,β-unsaturated ketosteroid in the young calf. Since changes in the nature of adrenocortical secretion have been observed during the early life of calves[2], it seemed appropriate to examine, first, the possibility of a relationship between progesterone and corticoid secretion; secondly, the relationship between the unknown steroid and progesterone; and thirdly, the chemical nature of the unknown steroid.

Adrenal venous blood was collected from 23 male and female Jersey and Guernsey calves, and the plasma was extracted in the manner previously described[1]. The results were not corrected for extraction losses, which were of the order of 40 per cent for progesterone; these losses would be slightly more for the unknown compound because of its greater polarity in the counter-current distribution system. In 10 animals the levels of cortisol and corticosterone were also determined in the adrenal venous plasma. For these estimations, the plasma, after treatment with 0·45 per cent sodium hydroxide, was extracted twice with an equal volume of ether followed by an equal volume of ethyl acetate. The dried residue from these extracts was acetylated with acetic anhydride labelled with carbon-14 in the presence of pyridine and carbon tetrachloride. The acetates so formed were separated on the *B* system of Bush[3]. The areas of radioactivity corresponding to cortisol and corticosterone acetates were measured by the use of a windowless gas-flow Geiger–Müller counter coupled to a recording ratemeter. Recoveries of cortisol by this method were of the order of 70 per cent.

The unknown compound was found to have the same R_F value in a ligroin/80 per cent methanol paper chromatographic system as 20α-hydroxypregn-4-en-3-one, and the R_F values of the acetates of these two compounds were also identical. In addition, the unknown had an ultra-violet absorption maximum at 240 mμ characteristic of an α,β-unsaturated ketosteroid; after treatment with concentrated sulphuric acid[4], it gave an absorption maximum at 290 mμ, as did 20α-hydroxypregn-4-en-3-one. On oxidation with chromium trioxide[5], the unknown yielded a compound chromatographically indistinguishable from progesterone. On the basis of this information the unknown was therefore identified as 20α-hydroxypregn-4-en-3-one, and this has since been confirmed by a comparison of the infra-red spectra of the two compounds. The concentration of this steroid in the adrenal venous blood was always considerably in excess of the concentration found in peripheral blood, indicating that it was in fact secreted by the adrenal glands.

The secretion of 20α-hydroxypregn-4-en-3-one in comparatively large amounts by the adrenal gland continued under our conditions during the first 58 days of post-natal life, and between days 58–64 there was a change-over to the secretion of progesterone. This change was not associated with any alteration in the cortisol/corticosterone ratio (Table 1).

20α-Hydroxypregn-4-en-3-one has not hitherto been recognized as an adrenal steroid; however, it has been isolated from a number of other tissues in man[6], sheep[7] and rat[8], where it is generally regarded as a metabolite of progesterone. Its presence in the adrenal venous blood of calves was unexpected, since the 20β epimer is the major compound of this type present in adult cattle[9–11]. The only activity attributed to 20α-hydroxypregn-4-en-3-one so far is that of a weak progestational agent[6], and it is not yet possible to assess the significance of this 20-hydroxy compound in the adrenal secretion of the young calf.

Table 1

Age of calf (days)	No. of animals and sex	Mean 20α-Hydroxypregn-4-en-3-one conc. μgm./100 ml. plasma	Ratio $\frac{\text{20α-Hydroxypregn-4-en-3-one}}{\text{Progesterone}}$	Ratio $\frac{\text{Cortisol}}{\text{Corticosterone}}$
1	6 male	3·2	>3·9	—
	2 male	—	—	>15·4
2	1 male	4·2	>2·1	12·5
23	1 male	22·3	20·3	1·4
32	1 male	12·0	>6·0	2·2
40	1 female	19·2	12·8	2·2
43	1 male	3·6	1·7	—
45	1 male	16·0	5·5	—
50	1 male	1·4	>1·4	—
56	1 male	8·3	1·0	—
58	2 male, 1 female	6·0	0·7	—
	1 male, 1 female	—	—	2·7
64	3 male	<1·9	<0·13	—
	1 male	—	—	3·6
69	1 male	<1·0	<0·04	—
80	1 female	<2·0	<0·2	—
334	1 male	<1·0	<0·2	3·9

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Penicillin as an Antigen

The ability of penicillin to function as an antigen, or more probably as a haptene, has only recently been described. Using the penicillin-sensitized red cell technique of Ley *et al.*[1], we have encountered eighteen sera from approximately 1,200 specimens, obtained from hospitalized patients, which have caused hæmagglutination. Preliminary testing was carried out on white porcelain tiles at room temperature using a 5·0 per cent suspension of group O, Rh-negative sensitized cells. Positive sera were titrated in 3 in. × ½ in. tubes at 37·0° C. and at 4·0° C. Control non-sensitized cells were included.

Subsequent investigation of the nature of the antibody involved in the reaction was mainly carried out on one serum which was arbitrarily scored as ++++ hæmagglutination by the tile method. Some characteristics of this serum are shown in Table 1.

Table 1

Hæmagglutinin titre (inactivated serum)	1/250
Hæmolysin titre (37·0° C. with complement)	1/64
Complement-fixation test (antigen–penicillin solution)	Positive fixation of complement
Heat stability of antibody	Withstands 56·0° C. for at least 6 hr.
*p*H range of hæmagglutination reaction	Active over range approximately 4·6–9·0

This patient had been receiving one mega unit of penicillin every 6 hr. for 4 weeks, and 7 days after cessation of therapy the hæmagglutinin titre rose to 1/1,000.

When a saline suspension of crystalline penicillin *G* was added in varying concentrations to varying dilutions of serum, an exponential-type curve was obtained when the reciprocals of the serum dilutions were plotted against the lowest concentrations of penicillin required to just inhibit hæmagglutination. The fact that proportionally higher concentrations of penicillin were needed to prevent hæmagglutination at the lower serum dilutions suggests that the antibody inhibition of penicillin is similar, in some respects, to that exerted by penicillinase.

The addition of penicillinase to penicillin-sensitized cells resulted in a considerable delay in the time required for hæmagglutination, but did not affect the final titres. This effect is apparently not due to destruction of penicillin adsorbed on to the cell surface since repeated washing of penicillinase-treated sensitized cells with 0·85 per cent saline restores fully the rate of subsequent agglutination by the serum.

Precipitin reactions both in tubes and by double diffusion techniques in agar gels have so far yielded negative results.

Our findings regarding the nature of this phenomenon differ in some respects from those described by Ley *et al.*[1]. These workers reported that certain sera gave positive hæmagglutination with the anti-globulin test. Repeated attempts with varying batches of anti-globulin sera have failed to substantiate this finding. In addition, direct Coombs's tests performed on the patient's own cells have also been negative, although the addition of penicillin solution to patient's washed cells results in agglutination indicating that antibody is apparently adsorbed on to the cell surface. These findings, however, appear to be explained by the results obtained from starch gel electrophoresis of the sera.

Attempts to characterize the antibody by conventional paper electrophoresis failed because it proved impossible to elute the antibody with saline from the paper. Ley *et al.*[1] were apparently able to elute antibody from sensitized cells by heating in saline at 54·0° C. for 15 min.; but we have been unable to confirm this observation. Starch gel electrophoresis according to the method of Smithies[2], however, proved a satisfactory procedure. After slicing the gels, one-half was stained with amido-black 10*B* for 30 sec. and cleared for approximately 10 min. in a mixture of methanol – distilled water – acetic acid (25 : 75 : 10 v/v). The high concentration of water prevented shrinkage of the gel for this period of time. The sliced portions of gel were matched, and fractions corresponding to the visualized separations in the stained half were cut from the unstained section. Each fraction was snap-frozen in dry ice and ether and then eluted with saline. The presence of antibody in each fraction was tested by the tube method. The starch remaining in the slots was examined by the same procedure. Antibody activity was consistently demonstrable in what Smithies[2] originally named pre-albumen$_1$ and pre-albumen$_2$. Pre-albumen$_2$ has now been identified as being acidic α_1-glyco-protein by Poulik and Smithies[3]. Pre-albumen$_1$ remains unidentified. In one patient difficulty was experienced in making all the antibody enter the gel and some activity remained in the slots. This patient, however, had a grossly abnormal protein pattern as a result of cirrhosis and secondary carcinomatous deposits in the liver. To be quite sure that antibody activity was associated with both fractions and not the result of trailing or irregular migration artefacts, the pre-albumen zone was differentiated by serial section and the titre of each fraction obtained was established. By this means two peaks of activity were demonstrated corresponding to the two pre-albumen zones. Control normal sera gave consistently negative results. It is stressed that the antibody has mobilities corresponding to the two pre-albumen zones, and may or may not be identical with these two fractions.

Further investigation of these sera is in progress, and it has been found that penicillin-sensitized bentonite particles can be substituted for red cells with satisfactory results.

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Metabolism of Sulphobromophthalein

Despite the great sensitivity and widespread use of sulphobromophthalein (BSP) retention as an index of liver function, little is known of the actual function(s) involved in the hepatic uptake and excretion of the dye. Presumably, sulphobromophthalein is bound to proteins in the serum and is thus conveyed to the liver, where the pigment–protein complex is broken. On release it is excreted into the bile as the free dye[1]. We have found, however, that pigments of sulphobromophthalein appearing in the bile and other biological fluids are chromatographically different from the parent compound[2], suggesting that a chemical modification is involved in the clearance of sulphobromophthalein by the liver.

Sulphobromophthalein in human bile, urine or serum was extracted with 3 vol. of acetone. The extract was taken to dryness and subjected to paper chromatography in an ascending system, employing *t*-butanol/water (30 : 17·3 v/v). In bile, three pigments, arbitrarily designated as BSP–*A*, –*B* and –*C*, were distinguishable from free sulphobromophthalein (Fig. 1). Since incubation of sulphobromophthalein with bile at 37° C. for 24 hr. gave rise only to free sulphobromophthalein, these products were not the result of an extrahepatic complex formation in the bile.

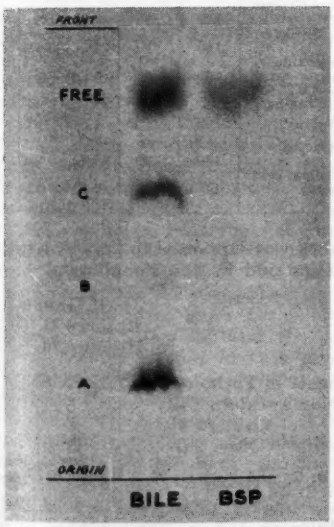

Fig. 1. Paper chromatogram of sulphobromophthalein pigments appearing in human bile

Based on their absorption at 575 mμ, the metabolites represented 65–75 per cent of the total sulphobromophthalein pigments appearing in human bile and urine, BSP–*A* usually being the most abundant. Only trace amounts of BSP–*A* and –*C* were obtained from serum. The metabolites have been similarly demonstrated in bile and urine from the rat, rabbit and dog.

Most of the proteins were removed during the acetone extraction, and the small amounts remaining were held at the origin during the chromatographic procedure. It is concluded, therefore, that the chemical differentiation between sulphobromophthalein and its metabolites is not dependent on protein.

To indicate that the production of sulphobromophthalein is a function of liver tissue, this substance was perfused through isolated liver from the rat. (We wish to thank Dr. G. L. Plaa and Dr. C. H. Hine for performing the perfusion phase of these experiments.) 90 per cent of the biliary sulphobromophthalein appeared as BSP–*A* and –*C*.

For further purification, sulphobromophthalein was extracted from bile or urine with acetone as above, dried and subjected to paper electrophoresis (Whatman 3 *MM* paper; 0·25 *M* acetic acid; 10 m.amp.; 1·5 hr.). The pigments (which move toward the anode) were eluted with water and the fractions of sulphobromophthalein were separated by chromatography in the *t*-butanol/water system. Each of the fractions was eluted with water and further purified by paper chromatography in an ascending system, using 5·2 parts *n*-butanol, 3·5 parts water and sufficient acetic acid to form a single-phase solution. Although these treatments nominally would be expected to result in a pure preparation, infra-red spectrographic observations indicated that significant impurities were still present.

The pigment characteristics of the purified BSP–*A* and –*C* were indistinguishable from those of the parent sulphobromophthalein; all three had identical absorption spectra in the visible range (single peak at 575 mμ) and identical curves when the absorption at 575 mμ was plotted against *p*H (indicator range was approximately 7·8–10·0).

The possibility that the metabolites are conjugates of sulphobromophthalein was investigated. BSP–*A* does not appear to be a glucuronide, since it is stable to hydrolysis with hydrochloric acid (0·2 *N*; 100° C.; 1 hr.), sodium hydroxide (0·2 *N*; 100° C.; 1 hr.) or with *B*-glucuronidase (*p*H 5·2; 37° C.; 25 hr.), and was negative for the presence of hexuronic acid when tested by the Dische reaction[3]. No hydroxamic acid was produced when the metabolite of sulphobromophthalein was treated with hydroxylamine reagent[4], suggesting the absence of an ester linkage in the molecule. Since ethereal sulphates are usually labile in hot dilute acid[5], it is unlikely that BSP–*A* is this type of conjugate.

Association of ninhydrin-positive material with the BSP–*A* fraction was consistently observed. A comparable chromatographic fraction from control bile or urine which contained no sulphobromophthalein was ninhydrin-negative. Rigorous hydrolysis with hydrochloric acid (6 *N*; 120° C.; 18 hr.) effected complete breakdown of BSP–*A*, yielding sulphobromophthalein, its decomposition products (moving with the front on paper), and a new substance(s) which was ninhydrin-positive and did not contain sulphobromophthalein. Final identification of the ninhydrin-positive compound(s) has been complicated

by the appearance, after similar hydrolytic treatment, of ninhydrin-positive impurities in the comparable chromatographic fraction of the control bile or urine. Further purification to facilitate identification of these metabolities is being carried out.

Some of these results were presented before the Pacific Coast Section of the Society for Experimental Biology and Medicine, San Francisco, on February 20, 1957.

While this manuscript was in preparation, Krebs and Brauer[8], utilizing alumina columns, were also able to isolate unidentified metabolites of sulphobromophthalein from bile.

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Anti-Thyroid Action of β-Aminoethyl*iso*thiouronium Dibromide in Rats

During the development of a screening test for goitrogenic activity of drugs, β-aminoethyl*iso*thiouronium dibromide, a radiation protective agent[1], was observed to have anti-thyroid activity. In view of possible long-term administration of this substance for prophylactic protection against irradiation, we are reporting our findings.

β-Aminoethyl*iso*thiouronium dibromide was prepared from ethylene imine and thiourea. 13·5 ml. ethylene imine (Chemirad Corp., Port Washington, New York) was dissolved in 80 ml. ether and the sediment removed. To this solution, chilled in a salt-ice bath, was added slowly a solution of 19·0 gm. thiourea and 57·8 ml. 48 per cent hydrobromic acid (s.g. 1·49) in 80 ml. methanol. After 6 hr., the precipitate of β-aminoethyl*iso*thiouronium dibromide which formed was removed and recrystallized three times from 80 per cent ethanol. The final product had a melting point of 194° C., corrected. Infra-red spectra of this material and authentic β-aminoethyl*iso*thiouronium dibromide obtained from Dr. D. G. Doherty were identical and a mixture melting point of the two was not depressed.

Female Sprague–Dawley rats weighing about 100 gm. were divided at random into six experimental groups of eight animals each and fed Rockland rat diet (1·20 mgm. iodide/100 gm. diet) *ad libitum*. The animals were given: (1) 400 mgm. β-aminoethyl*iso*thiouronium dibromide/kgm. body-wt./day; (2) 50 mgm. 6-propylthiouracil/kgm. body-wt./day; (3) 120γ L-thyroxine/kgm. body-wt./day; (4) 400 mgm. β-aminoethyl*iso*thiouronium dibromide + 120γ L-thyroxine/kgm. body-wt./day; and (5) 50 mgm. 6-propylthiouracil + 120γ L-thyroxine/kgm. body-wt./day by gavage daily as a freshly prepared suspension in 10 per cent gum acacia. A control group was given 10 per cent gum acacia alone. Daily weights were obtained. On the last day of drug administration, 0·05 μc. iodine-131 in 0·1 – 0·2 ml. solution was injected intraperitoneally. The animals were killed 24 hr. later, and the larynx with the thyroid gland attached was removed and assayed for radioactivity. The thyroid then was dissected carefully from the larynx and weighed.

The results are summarized in Table 1. The administration of β-aminoethyl*iso*thiouronium dibromide resulted in less iodine uptake and in some thyroid enlargement ($P < 0·05$). 6-propylthiouracil, which is known to be a powerful goitrogen, produced similar, though greater, changes. The increase in thyroid weight was prevented in both cases by the simultaneous administration of L-thyroxine. Thiourea derivatives are known to block the formation of thyroid hormone[2]. It is not surprising, therefore, that β-aminoethyl*iso*thiouronium dibromide, which is related structurally to these compounds, results in depression of iodine uptake and thyroid enlargement. While hypothyroid animals perhaps are somewhat more resistant to irradiation[3], the radiation protective action of β-aminoethyl*iso*thiouronium dibromide is greatest during the half-hour immediately following its administration, and in acute radiation experiments it is not likely that the anti-thyroid action of β-aminoethyl*iso*thiouronium dibromide explains any radiation protective action. However, it is of interest that cysteamine, another radiation protective compound, also has anti-thyroid activity[4].

Table 1. Effect of β-Aminoethyl*iso*thiouronium Dibromide (AET) and Propylthiouracil (PTU) on the Iodine Uptake and Thyroid Weight of Rats

Drug and dosage (10 days)	Average body-weights		Thyroid weight (mgm./100 gm. body-weight)	24-hr. radioiodine uptake (per cent)
	Initial (gm.)	Final (gm.)		
400 mgm. AET/kgm. daily	140	180	9·56±1·0	3·64±0·40
50 mgm. PTU/kgm. daily	160	210	16·0 ±0·73	0·68±0·18
120γ L-thyroxine/kgm. daily	160	200	6·06±0·88	1·62±0·48
400 mgm. AET + 120γ L-thyroxine/kgm. daily	135	190	7·14±0·68	0·19±0·04
50 mgm. PTU + 120γ L-thyroxine/kgm. daily	140	180	8·12±0·74	0·25±0·10
Control (10 per cent gum acacia)	140	190	7·62±0·33	16·0 ±1·0

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Effect of Salicylate on Blood and Liver Xanthine Dehydrogenase of Rats

Milk and liver xanthine oxidase are inhibited by sodium salicylate *in vitro*[1]. Bergel *et al.*[2] were able to utilize this property for the stabilization of xanthine oxidase by adding salicylate to the process of purification of the enzyme.

Adult white rats of the Wistar strain were used for the determination of the *in vivo* effect of salicylate on blood and liver xanthine dehydrogenase. Rats were injected intraperitoneally by a single dose of 0·5 mgm. of sodium salicylate per gm. body-weight, and xanthine dehydrogenase activity on liver and blood serum determined 4 hr. after the injection by methods previously described[3].

Blood serum of normal rats showed values of 29·0 ± 6·9 μgm. formazan/ml. serum/30 min. at 37° C. In the injected rats the average value was 40·4 ± 5·4 μgm. formazan/ml. serum/30 min. These results show an increase of xanthine dehydrogenase activity which is statistically significant (normal, $t = 4·2$, $P < 1$ per cent; injected, $t = 7·4$, $P < 1$ per cent). 24 hr. after the injection, this value decreased to 25·2 ± 7·0 ($t = 3·6$, $P < 2$ per cent). On the other hand, liver from injected rats presented a loss (82·67 per cent inhibition) in xanthine dehydrogenase activity (Table 1).

Table 1. Effect of Salicylate in Rat Liver Xanthine Dehydrogenase*

	Without dialysis		With dialysis	
	Mean	Range	Mean	Range
Normal	675	217–1,865	891	257–1,814
Salicylate	117	0– 366	254	128– 308
Inhibition (per cent)	82·67		71·50	

* μgm. formazan/gm. dry liver/60 min. at 37° C.

Since salicylate could be removed from the enzyme by dialysis, with full restoration of the enzyme activity[1] even after prolonged association[2], we were interested to know if this *in vivo* inhibition of rat liver xanthine dehydrogenase by salicylate was also restored by dialysis. Dialysis of liver homogenate against distilled water in the cold gave the results summarized in Table 1.

In vitro experiments with a final concentration of *M*/10 sodium salicylate showed an inhibition of rat-liver xanthine dehydrogenase activity (60–70 per cent inhibition) and also of the blood-serum enzyme (50–100 per cent inhibition).

The low restoration of xanthine dehydrogenase activity obtained by dialysis of liver homogenate (Table 1) from injected rats shows that the *in vivo* inhibition of the xanthine dehydrogenase activity is possibly not only due to a loose bond (split by dialysis) between the salicylate and the enzyme. Definitive liver damage occurs in rats given 400 mgm. of sodium salicylate/kgm./day[4]. Since the loss of enzyme protein from liver tissue seems to be a general phenomenon which accompanies cell destruction in certain conditions[5], it seems probable that with the dose used by us (500 mgm./kgm.) the flow of the liver xanthine dehydrogenase, which is a soluble protein[6], to the blood serum results in a decrease of the enzyme activity in liver and consequently an increase of the blood serum xanthine dehydrogenase activity.

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Re-ingestion in *Lepus capensis* L. and *Ochotona roylei* Ogilby

The domestic rabbit produces special soft fæcal pellets which are normally taken back into the stomach direct from the anus[1,2]. This behaviour, which has been termed coprophagy, refection[2] or more appropriately re-ingestion[3], has been observed in wild rabbits[4] where it has been shown to follow a regular daily rhythm, beginning about sunrise and ending in the early afternoon[3,5].

Re-ingestion, following a similar rhythm, has since been observed in *Lepus europaeus*[6], *L. californicus*[7], *L. townsendii*, *L. americanus* and *Sylvilagus transitionalis*[8], and evidence has been reported of re-ingestion in *S. palustris*[9] and *S. floridanus*[10].

The present communication reports the occurrence of re-ingestion in another leporid and the first report from the Ochotonidae, thus supporting Watson and Taylor's[6] suggestion that re-ingestion is a normal feature of lagomorph biology.

The material was collected from an ablation valley on the northern side of the Barpu Glacier, in the Gilgit Agency of Pakistan, at an altitude of 11,000–13,000 ft. The lower part of the valley was rough grassland where hares (*Lepus capensis*) were abundant, and higher up this was replaced by a juniper association (*Juniperus turkestanica* Korn) growing on boulder banks, where the pikas (*Ochotona roylei*) lived. Three pikas and 19 hares were shot at different times of the day and nine pikas were trapped at night.

Table 1 groups the 19 hares examined into 2-hr. periods from 0600 hr. to 2000 hr. Between 0800 hr. and 1400 hr. soft fæces were found in the recta, the criterion of active re-ingestion[3], and in some of these hares amorphous fæcal material was also found in the cardiac end of the stomach. In one hare, which had a tapeworm in the duodenum, a gravid proglottis was found with the fæcal material in the stomach. Since no hares were shot at night, these observations

Table 1. Incidence of Re-ingestion in *L. capensis*

Time	No. examined	No. with soft fæces in rectum
0600 hr.	1	0
0800	5	0
1000	3	1
1200	2	2
1400	5	5
1600	—	—
1800	—	—
2000	3	0
Total	19	8

are not sufficient to show the full rhythm; but the incidence of re-ingestion conforms closely to that reported for other species of *Lepus*.

Among the 12 pikas examined four had soft pellets in the rectum and six had soft pellets or amorphous material in the cardiac end of the stomach. In one animal hard pellets were seen in the rectum posteriorly and soft pellets near the colon, and in another soft pellets were seen near the anus and hard pellets near the colon, indicating that these two animals were respectively beginning and ending re-ingestion. The daily rhythm in *Ochotona* does not emerge from this material; but, since the three animals shot in the daytime did not have soft fæces in the rectum and four of the animals trapped at night did, re-ingestion in *Ochotona* may occur at night in contrast to the Leporidae so far examined.

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Ineffectiveness of Molybdenum, Osmium and Cobalt in Dietary Necrotic Liver Degeneration

In our past, comprehensive experience in the fractionation and purification of Factor 3 from various source materials, using the prophylactic rat test against dietary liver necrosis as an assay, it has been obvious that the Factor 3 effect was caused by a highly specific, potent, protective ingredient. The latter was recognized to be an organic selenium compound[1]; this, in turn, led to the realization that selenium is an essential micronutrient. Selenite-selenium was found to prevent necrotic liver degeneration, with a 50 per cent effective dose-level of 2·2 μgm. per cent and full protection at levels of approximately 5 μgm. per cent selenium in the diet. Factor 3-selenium is 3–5 times as potent[2].

Bunyan, Edwin and Green, on the other hand, have recently published preliminary results suggestive of protective effects of molybdenum, osmium and cobalt[3]. Their results stand in distinct contrast to earlier, unpublished results of our own. In 1953, for example, when it was discovered that molybdenum is essential for normal xanthine oxidase-levels in tissues[4,5], we had observed that 1 mgm. per cent of molybdic anhydride in the diet did not materially influence the development of dietary liver necrosis.

We have attempted to verify under our experimental conditions the findings of Bunyan and collaborators, with negative results (Table 1). Experimental details are described elsewhere[6,7]. The 30 per cent *Torula* yeast diet and weanling, inbred Fischer 344 strain of rats were employed, and the pre-depletion method was used, that is, the animals were kept for 13 days on the basal diet before start of the supplementation of test-substances. Molybdenum, osmium and cobalt, either alone or in combination, were tested at various dose-levels. They were without effect against liver necrosis even at 200, 200 and 400 μgm. per 100 gm. of diet, respectively.

Table 1. Ineffectiveness of Molybdenum, Osmium and Cobalt in Dietary Necrotic Liver Degeneration

Supplement	Element μgm. per cent in diet	No. of rats		Average velocity*
		Total	Survivors on 30th day	
Sodium selenite†	controls	44	4	4·45
	2	20	11	1·90
	4	10	9	0·36
	10	20	20	0
Ammonium molybdate	controls	10	1	4·4
	50	10	2	4·0
	100	10	0	4·8
	200	10	1	4·7
Osmium tetroxide	controls	37	2	4·7
	50	10	1	4·3
	100	18	1	4·8
	200	10	0	4·8
Cobaltous acetate	controls	20	2	4·5
	50	10	2	3·9
	100	18	3	4·3
	200	10	1	4·4
	400	18	2	4·2
Combination of ammonium molybdate, osmium tetroxide and cobaltous acetate	controls	20	2	4·2
	25+50+50	10	1	4·6
	50+100+100	10	2	4·1
	100+200+200	19	2	4·5

* Group average of reciprocals of individual survival-times (× 100). All experiments were terminated on the thirtieth day, and velocity of 0 was assigned to survivors.
† Published previously (ref. 2).

The question arises as to what possible cause there may be for the discrepancy between the results of Bunyan *et al.* and ours. It is our experience that differences such as those reported by Bunyan *et al.* are not significant if they are not consolidated by repetition of the experiment. However, the authors observed at least the delaying effect of the *combination* of the three trace elements twice. The statistical validity of such results can be assessed if the velocity of the development of the disease (V_{st}) is calculated for each group by computation from the individual reciprocals of the survival times[6]. For animals surviving indefinitely, $V_{st} \rightarrow 0$. Among various alternative explanations, the three trace elements may act through influencing appetite, Results available on the toxicity of molybdenum, osmium and cobalt salts are sporadic, but it appears that the doses used by Bunyan *et al.* are below those reported by others to be toxic. However, it must be kept in mind that the minimum chronic toxic dose-levels vary considerably with the general composition of diets. A restriction of dietary intake, or its reduction by other means such as chronic poisoning, delays or completely prevents the development of liver necrosis[8]. A chronic, toxic influence could make itself felt more effectively in their studies than in ours, since they require on the average 55–60 days for the production of liver necrosis, with a wide range of survival-times, and survivors in the control groups even at the hundredth day. This compares with an average survival-time of 21 days under our conditions, with much less statistical variation but small numbers of survivors after 30 days. Our animals died approximately 8 days after the start of the supplementation of the trace element. Food consumption was measured in 10 of the groups listed in Table 1. There were no significant differences. Interaction between the trace elements and some essential ingredient in the

diet may also play a part. The explanation that molybdenum, osmium and cobalt act through participation in oxidation-reduction mechanisms within the organism, thus alleviating the defect existing in intermediary metabolism under pre-necrotic conditions[9], also may pertain, as mentioned by Bunyan *et al.*

It is obvious from our findings, however, that molybdenum, osmium and cobalt are not of primary importance in the prevention of dietary necrotic liver degeneration. If they have a moderating influence at all, it would be of a secondary nature.

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Fractionation of Brain Extracts for Acid Phosphatase-elevating Activity

In a previous communication[1] it was demonstrated that *in vitro* incubation of rat pituitary with whole aqueous hypothalamic extract increased acid phosphatase activity in the pituitary gland. Temporal lobe extract had no such effect. The results of a study of the effect of individual fractions of the extracts are given below.

Ten excised portions of the base of rabbit brains (median eminence, base of the third ventricle and the adjacent parts; below, hypothalamus), with a total weight of 3·33 gm., were homogenized in 50 ml. 0·45 per cent sodium chloride solution and frozen at − 20° C. The following day the insoluble material was separated by centrifugation at *p*H 6·8 and the extract was divided into the following three fractions, which were lyophilized: (I) *p*H 6·8–7·0, 25 per cent ethyl alcohol; (II) *p*H 4·8 ± 0·1, 40 per cent ethyl alcohol; (III) lyophilizate of the residue (low molecular substances). Aliquots of the individual fractions, corresponding to 1/10 of a rabbit hypothalamus, were mixed with 0·5 ml. distilled water containing homogenate of 1/3 rat pituitary gland, and acid phosphatase activity was determined in the mixture by the King–Armstrong method, at *p*H 5·3. Activity was expressed as King–Armstrong units/gm. pituitary (Table 1). Acid phosphatase activity of the homogenate was elevated only by the third (non-protein) fraction of hypothalamic extract. Fraction III did not itself contain acid phosphatase.

Although in the preceding experiments[1] crude temporal lobe extract had no effect on acid phosphatase activity in the pituitary gland, a further series of experiments was carried out, in which fraction III was prepared in the same way from hypothalamus and from temporal lobe. Ten rabbit hypothalami weighing 3·54 gm. yielded 200 mgm. of fraction III, and ten portions of temporal lobe weighing 3·73 gm. yielded 205 mgm. In both cases the brains were homogenized in 0·225 per cent sodium chloride solution. Equivalents of 1/10 or 1/20 of one excised brain portion were again mixed with 0·5 ml. pituitary homogenate and acid phosphatase activity expressed in King–Armstrong units/gm. (Table 2). The factor elevating acid phosphatase activity in pituitary homogenate is present in fraction III of both the hypothalamus and temporal lobe extract. In the latter it is discernibly lower.

In the final experiment in this series the influence of fraction III of both brain extracts on the acid phosphatase activity of other tissues was determined. 50 mgm. rat liver or kidney was homogenized in 10 ml. water; 0·5 ml. of this homogenate was then mixed with amounts of fraction III corresponding

Table 1

Fraction	0	I	II	III	III (without homogenate)
No. of experiments	18	14	10	10	6
Mean acid phosphatase activity (King–Armstrong units/gm. ± σ_m)	1·88 ± 0·108	1·23 ± 0·082	1·11 ± 0·296	2·86 ± 0·114	0·0 ± 0·0

Table 2

Origin of the low-molecular fraction and concentration (equivalents of one part of brain)	0	Hypoth. 1/10	L. temp. 1/10	Hypoth. 1/20	L. temp. 1/20
No. of experiments	30	12	12	18	17
Mean acid phosphatase activity (King–Armstrong units/gm. ± σ_m)	1·76 ± 0·12	4·32 ± 0·114	3·66 ± 0·147	2·82 ± 0·162	2·08 ± 0·150

Table 3

Homogenate of	Liver			Kidney		
Origin of the low-molecular fraction	0	Hypoth.	L. temp.	0	Hypoth.	L. temp.
No. of experiments	8	8	7	8	8	4
Mean acid phosphatase activity (King–Armstrong units/gm. ± σ_m)	3·52 ± 0·133	6·37 ± 0·252	5·20 ± 0·151	2·81 ± 0·420	4·64 ± 0·420	6·40 ± 0·0

to 1/10 hypothalamus or temporal lobe. Acid phosphatase activity was again expressed in King–Armstrong units/gm. fresh tissue in the homogenate (Table 3). Fraction III of the brain extracts also raised acid phosphatase activity in liver and kidney homogenate.

No explanation has yet been found for the discrepancy between the effect of fraction III of the temporal lobe extract and the ineffectiveness of crude aqueous extract of this lobe. In spite of the obvious non-specificity of the acid phosphatase-elevating activity of the fraction III of hypothalamic extract, we cannot exclude the possibility that the active factor is a hypophysiotrophic hypothalamic hormone. It is probable[2] that it is linked with the production of the thyrotrophic hormone of the pituitary gland.

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Failure of Acetylcholine Release in Tick Paralysis

A motor paralysis can be caused in a number of mammalian species, including man, by the continued attachment of the Rocky Mountain wood tick, *Dermacentor andersoni* Stiles[1]. The symptoms are manifested as a flaccid paralysis which begins in the hind limbs and ascends until ultimately the bulbar respiratory centres are involved.

Of the common laboratory animals, only dogs, guinea pigs and hamsters are subject to paralysis following the bite of this tick, and they are not invariably affected. We, and Gregson[2], have found that the only animal which has always been affected is the ground hog *Marmota flaviventris avara* (Bangs), the only variable being the time taken for the symptoms to appear. This latter is apparently dependent upon the number of attached ticks and their rate of feeding. The experiments to be described here have all been performed on ground hogs, using ticks that were collected from their natural environment in the vicinity of Kamloops, British Columbia. The animals show the typical picture of an ascending flaccid paralysis which ultimately involves the muscles of respiration. The only inconsistency in this progression of the condition is that very early the normal piercing cry of the animal is lost and is replaced by a hoarse grunt, seemingly due to involvement of the vocal cords. Another characteristic feature of tick paralysis as evidenced in most animals is the rapid disappearance of the symptoms following removal of the tick. This is not true of the condition in ground hogs in which death frequently ensues once the paralysis has become evident, even though the tick is removed. There is good evidence that the paralysis is not caused by the transmission to the host of a virus or of a micro-organism, but that it is due to a toxin secreted by the tick[1].

There can be little doubt that there exists in this condition a peripheral neuromuscular block. This has been shown by Rose and Gregson[3] and by Murnaghan[4] to be true in other animals; and we, as well as Gregson[2], have confirmed it in ground hogs. Adult ground hogs were paralysed 18–36 hr. after 4–7 partially engorged female ticks were allowed to attach themselves, and experiments were conducted at a time when respiratory difficulty first became noticeable. Records of the twitches of the gastrocnemius, tibialis anterior and brachialis muscles have been made following maximal electrical stimulation of the appropriate motor nerves, and the tensions developed in the muscles of fully paralysed animals are never more than 5 per cent of those found in controls. The response to repetitive stimulation (twenty impulses per sec.) is poorly maintained, and there is no evidence of a post-tetanic potentiation of the response to a single shock such as may be attained in a partially curarized preparation. The muscles remain directly excitable throughout.

Murnaghan[4] has reported that in one fully paralysed dog the threshold dose of acetylcholine required to produce a muscle twitch following intra-arterial injection was much reduced, resembling the enhanced sensitivity found after denervation. We have failed to confirm this in four fully paralysed ground hogs. The concentrations of acetylcholine required to elicit a detectable electromyographic response (recorded with a concentric needle electrode) was the same for both control and paralysed animals.

Perfusion of the hind limb of ground hogs was achieved following cannulation of the common iliac artery and vein. A 'finger' pump was used to give a pulsatile flow of the perfusion medium, which consisted either of reconstituted human serum or Tyrode's solution, both equilibrated with 95 per cent oxygen–5 per cent carbon dioxide and containing 10 mgm./l. of eserine sulphate. The main trunk of the sciatic nerve was maximally stimulated at a frequency of 10/sec. Acetylcholine was assayed by observing the ability of the effluent perfusion fluid to depress the blood pressure of the eviscerated cat.

The results, which are shown in Table 1, indicate clearly that in the paralysed animals there is a lack of release of acetylcholine into the perfusion fluid as a response to stimulation of the sciatic nerve. Whether this failure is due to a deficient synthesis of acetylcholine or to an impaired release of the substance from the endings of the motor nerves must await further investigation. In either event, however, it is difficult to allow that this peripheral action brought about by

Table 1. Release of Acetylcholine in Perfused Ground Hog Limbs.
Acetylcholine gm./min. × 10^{-9}

	Unstimulated			Stimulated		
	First 5-min. period	Second 5-min. period	Third 5-min. period after stimulation	First 5-min. period	Second 5-min. period	Third 5-min. period
Normal	6·8 0 8·9	2·1 0 10	0 1·4 —	46 12 25	28 13 —	11 8·2 —
Paralysed	4·0 0 1·9 0	4·1 0 3·1 7·0	0 0 5·3 0	4·6 3·4 5·6 0	4·6 0 7·1 0	3·3 0 8·0 0

the tick toxin can be the only one. *A priori* there seems no reason why any given muscle should be preferentially affected, and one would expect to see a gradual generalized weakening of the skeletal musculature rather than the orderly ascending progression of paralysis which is the observed fact. We conclude that in addition to the peripheral, there is likely to be some central nervous system component to the syndrome which is as yet undefined.

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Colloid Osmotic Pressure of Rheumatoid Synovial Fluid

THE colloid osmotic pressure of rheumatoid synovial fluid samples was measured before and after intra-articular hydrocortisone treatment using collodium membranes and a hydrostatic compensation system[1]. Previously, it had been found that contents of vacuum-dried synovial fluid adsorbed decreased volumes of water after cortisone treatment[2]. The results are presented in Tables 1 and 2, but a detailed account on the material is given elsewhere[3].

Table 1. CHANGES OF COLLOID OSMOTIC PRESSURE (IN CM. WATER) OF RHEUMATOID SYNOVIAL FLUID IN CONNEXION WITH HYDROCORTISONE TREATMENT

Clinical effect	No. of cases	Treatment		Difference	P
		Before	After		
Poor	6	42·3	38·2	−4·1	0·05
Moderate	7	42·3	38·0	−4·3	0·05
Excellent	11	42·4	33·0	−9·4	0·001
All cases	24	42·4	35·7	−6·7	0·001

Table 2. COLLOID OSMOTIC PRESSURE (IN CM. WATER) OF SYNOVIAL FLUID AND SIZE OF THE EFFUSION (CASES OF STAGES I–II ONLY; $P < 0·05$ WITH ANALYSIS OF VARIANCE)

Size	No. of cases	Mean and range	
Moderate	7	41·8	(38–46)
Large	8	44·3	(40–58)
Very large	6	46·3	(42–51)

The colloid osmotic pressure could be correlated with the total protein ($r = 0·66$; $P < 0·001$) and with the blood erythrocyte sedimentation rate ($r = 0·70$, $P < 0·001$) but not with the concentration of synovial fluid sodium, potassium, chloride or hyaluronate or with the intrinsic viscosity. With the size of effusion a relation could be established only in the cases of Stages I–II (roentgenologically non-advanced).

It is concluded that the changes in the protein concentration and consequently in the colloid osmotic pressure of the synovial fluid are of importance in the formation and disappearance of the effusion. It may be argued that if the protein actually passes into the synovial cavity, its colloid osmotic pressure cannot have any significance. Admittedly, in the genesis of traumatic effusions a permeability damage is more important, and in the anatomically more advanced cases with stiff joints the colloid osmotic pressure is generally lower ($P < 0·001$) and seems immaterial. However, submitting the observed clinical and chemical correlations as circumstantial evidence, we suggest that the increased colloid osmotic pressure may prevent the normal resorption of fluid from the synovial cavity in rheumatoid arthritis.

The polysaccharide does not seem important in the maintenance of the colloid osmotic pressure. The significance of the qualitative and quantitative changes in the hyaluronate should be sought from the analogies with the connective tissue response to inflammation.

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Inactivation of Spores of *Bacillus anthracis* by γ-Radiation

THE bactericidal effect of ionizing radiation has been recognized for many years; but it is only recently that serious attention has been given to this method of sterilization for foodstuffs[1] and for pharmaceutical and other products[2,3]. This is due mainly to the increased availability of radioactive isotopes. In this respect γ-radiation seems to be the most useful due to its effective depth of penetration, and the most convenient sources of γ-radiation are cobalt-60 and cæsium-137.

The present communication records the results obtained from a preliminary investigation into the sterilizing efficiency of γ-radiation against spores of *Bacillus anthracis*. Eight strains of *B. anthracis* were used.

Spore suspensions were prepared by inoculating 5 ml. of 'Yeastrel' broth with the test organism; after incubation for 72 hr. the culture was heated at 60° C. for 30 min. The approximate number of viable spores remaining was determined by adding 0·1 ml. of the heated suspension to 100 ml. of broth and then spreading 0·1 ml. of the diluted material over the surface of a dish of 'Yeastrel' agar. If at least 100 colonies grew, this indicated a viable count of at least 10^6 spores/ml. and the suspension was used in the experiment. If less than 100 colonies grew, the suspension was rejected and another culture prepared.

Approximately 0·5 gm. samples of washed goat hair were compressed in test-tubes 15 cm. × 1·5 cm., stoppered with cotton-wool plugs and sterilized by autoclaving at 15 lb./sq. in. for 15 min. Each sample of hair was contaminated by adding to the tube 1 ml. of a spore suspension in broth of the test organism. The samples were then dried at 56° C. for 48 hr. and allowed to stand in the incubator at 22° C. for 4 weeks.

Samples of contaminated hair were treated with increasing doses of γ-rays from a cobalt-60 source. The dose-rate was varied (from 10^4 rad/hr. to

2×10^5 rad/hr.) by altering the distance of the samples from the source. All irradiations were carried out at room temperature, and doses are given with a maximum error of ± 5 per cent.

In a pilot experiment six of the eight strains of *B. anthracis* were used. Each organism was exposed to radiation from a cobalt source at 200,000 rad/hr. for periods of 3, 7, 9 and 15 hr. (actual doses: 0·58, 1·42, 1·80 and $3·0 \times 10^6$ rad).

After irradiation, each tube was tested for sterility by adding 10 ml. of 'Yeastrel' broth and incubating at 37° C. for 2 and 28 days.

Tubes which had not been irradiated were included as controls and all these showed growth in 48 hr. Similarly, growth was obtained in 48 hr. in all tubes exposed to a radiation dose of $0·58 \times 10^6$ rad, but all other tubes were sterile even after 28 days incubation (Table 1).

Table 1. Viability of Spores after γ-Radiation

B. anthracis strain	Radiation dose ($\times 10^6$ rad)				
	0·0*	0·58	1·42	1·80	3·0
1	+	+	−	−	−
2	+	+	−	−	−
3	+	+	−	−	−
4	+	+	−	−	−
5	+	+	−	−	−
6	+	+	−	−	−

* Control; +, growth after 48 hr.; −, no growth after 28 days.

A second experiment was carried out using these six strains of *B. anthracis*, together with two others, more recently isolated (kindly supplied by Prof. D. T. Robinson, Liverpool Public Health Laboratory). The organisms were exposed to a graded series of radiation doses varying from $0·8 \times 10^6$ rad to $2·1 \times 10^6$ rad. The accuracy of the radiation dose was again ± 5 per cent.

In a third series, the two recently isolated strains were irradiated in the range $1·0–1·4 \times 10^6$ rad.

The results of all three series are combined in Table 2.

Table 2

B. anthracis strain	Radiation dose ($\times 10^6$ rad)											
	0*	0·8	0·9	1·0	1·1	1·2	1·35	1·4	1·5	1·7	1·9	2·1
1	+	+	+	+	+	+	+	+	−	−	−	−
2	+	+	+	+	−	−	−	−	−	−	−	−
3	+	+	+	−	−	−	−	*NT*	−	−	−	−
4	+	+	*NT*	*NT*	*NT*	*NT*	*NT*	−	*NT*	*NT*	*NT*	*NT*
5	+	+	+	+	+	−	−	−	−	−	−	−
6	+	+	+	+	−	−	−	*NT*	−	−	−	−
7	+	*NT*	*NT*	+	+	+	*NT*	−	*NT*	*NT*	*NT*	*NT*
8	+	*NT*	*NT*	+	+	−	*NT*	−	*NT*	*NT*	*NT*	*NT*

* Control; +, growth after 48 hr.; −, no growth after 28 days; *NT*, not tested at this level.

From this it will be seen that the most sensitive strain of *B. anthracis* failed to grow after $1·0 \times 10^6$ rad while the most resistant needed $1·5 \times 10^6$ rad for inactivation.

These experiments were carried out with the view of determining the applicability of γ-radiation to the sterilization of imported goat hair. In the United Kingdom this substance is at present subjected to a formaldehyde treatment as laid down in the Anthrax Act of 1919.

On the basis of our results a dose of $1·5 \times 10^6$ rad is sufficient to ensure the inactivation of a high concentration of spores of all the strains of anthrax used. Further experiments are in hand using a larger number of strains to find more certainly the natural variation in radiation resistance. Pending the completion of the experiment we suggest that a minimum dose of $2·0 \times 10^6$ rad would provide a sufficient margin of safety in an industrial process for the inactivation of *B. anthracis* in baled goat hair.

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Phagocytosis and Cell Division

Most investigators believe that reticulo-endothelial cells, through ingestion of the antigen, play an initial part in the synthesis of antibody[1,2]. Study of phagocytosis of particulate antigens lends support to this concept[3]. Since antibody is merely one form of protein, its formation could theoretically occur immediately; however, it appears to be delayed several hours or days[4].

It has recently been thought that when antibody does appear it is most closely associated not with the reticulo-endothelial cell but with the plasma cell[5], although lymphocytes[6] and eosinophils have also been implicated[7].

Some investigators believe that plasma cells and lymphocytes are derived from reticulo-endothelial cells and that during the process of division and differentiation the antibody-producing mechanism is automatically transferred to the daughter cell[8]. However, other workers feel that some way other than division must be postulated to explain transfer of the antibody stimulus from the reticulo-endothelial cell to the plasma cell. They point out that cells which have ingested large quantities of carbon are unable to divide, and conclude that reticulo-endothelial cells after ingestion of the antibody could not divide and differentiate into plasma cells[9].

While studying the process of phagocytosis in L strain fibroblasts, we made some observations which may be applicable to this problem. These cells were grown routinely in suspension tissue culture as single cells, in Eagle's medium and 10 per cent horse serum as described previously[10]. Cultures (70 c.c. in volume) were incubated for 1 hr. at 37·5° with 1 mgm. carmine particles. Following incubation, the cells were washed free of carmine and resuspended in fresh medium. If the incubation was continued for 3 hr., the cells ingested a great many carmine particles and were unable to divide, and the cells usually died over a period of 3–5 days. However, cells which had ingested only 3–6 carmine particles per cell underwent normal division with a generation-time of approximately 28 hr., similar to the control cultures. No abnormal mitotic figures were noted, and the particles distributed themselves in the cytoplasm during mitosis (Fig. 1).

Some investigators believe that fibroblasts and macrophages are derived from reticulo-endothelial cells and that they may revert to their original form[11],

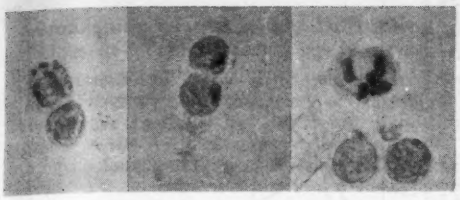

Fig. 1. Several fibroblasts have phagocytized carmine granules. Two cells are in anaphase. Aceto-carmine stain. (× 450)

Regardless of the truth of this statement, our experiments show that a phagocytic cell may ingest large amounts of foreign material and afterwards undergo division. By analogy, it lends support to those who believe that the phagocytic reticulo-endothelial cell may ingest a foreign protein antigen and retain the ability to divide. If a reticulo-endothelial cell does differentiate into a plasma cell, these observations also support the unified concept of ingestion of antigen and production of antibody within a single cell.

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Inhibitory Action of Amino-Acid Esters on the Production of Extracellular Amylase by *Penicillium chrysogenum*

WASHED mycelium of *Penicillium chrysogenum* will not synthesize amylase except in the presence of starch. Production cannot be increased by adding amino-acids to the medium.

Amylase production by the mycelium of washed *Penicillium chrysogenum* strain Wis. 49–133 was studied. The mould was grown for 48 hr. in a medium containing soluble starch. The dry-matter content was 0·62 gm./100 ml. of incubated medium. The experimental conditions were as follows: *Penicillium chrysogenum* was grown at 24° C. in 200 ml. of medium in a 500-ml. Erlenmeyer flask on a rotary shaker (300 r.p.m., 2 cm. radius). The medium for the inoculum was composed of (per cent) glucose, 2; sodium nitrate, 3; potassium dihydrogen phosphate, 0·1; $FeSO_4.7H_2O$, 0·1; $MgSO_4.7H_2O$, 0·05; potassium chloride, 0·05; it was adjusted to *p*H 6·5 before sterilization and 0·5 per cent calcium carbonate was added before inoculation. The flasks were inoculated with a spore suspension. Mycelium was produced in the same medium. The energy source varied, but the concentration was always 2 per cent. Inoculations were carried out with 3-day-old inoculum. Mycelium production lasted for 48 or 72 hr., depending on the source of energy. Washing was done with 6 vol. of distilled water with filtering. The dry-matter content was determined by drying at 105° C. after filtering and washing with acetic acid. Enzyme production proceeded on a rotary shaker at 24° C. Mycelium suspended in 50 ml. of distilled water and 25 ml. of distilled water, or the indicated substance dissolved in distilled water, was added to 25 ml. of 0·4 per cent potassium dihydrogen phosphate and 0·4 per cent soluble starch (adjusted with potassium hydroxide to *p*H 6·5 before sterilization), in a 500-ml. Erlenmeyer flask. Amylase was determined in filtered samples of the incubated medium at 28° C. using the method of Smith and Roe[1]. Every step of the experiments was carried out under aseptic conditions and was afterwards tested for sterility.

Table 1 illustrates enzyme production as a function of time. The results are typical of induced enzyme synthesis. Identical results were obtained with mycelium grown on a wide variety of energy sources (glucose, lactose, sorbitol and glycerol), and most strikingly, even when the mould had been grown in a medium containing starch. Amino-acid esters have been found to be capable of inhibiting this enzyme production. Table 1 shows experiments carried out with glycine ethyl ester. Results similar to these were obtained with D-phenylalanine methyl ester and L-*iso*leucine methyl ester. A mixture of glycine and ethanol corresponding to a 10^{-2} *M* concentration of glycine ethyl ester, 10^{-2} *M* glycine amide and 10^{-2} *M* glycylglycine ethyl ester, were found to have no effect on enzyme production. The washed mycelia of mould, grown on various energy sources, all displayed the same behaviour in our inhibition experiments.

Table 1

Time (hr.)	Amylase (U/100 ml.)					
	Glycine ethyl ester hydrochloride (*M*)				Glycine and ethanol (see text)	
	10^{-2}	5×10^{-3}	10^{-3}	5×10^{-4}		
0	3	1	1	1	0	0
2	0	1	2	0	0	0
4	1	2	20	27	28	31
6	4	13	92	139	148	156
8	9	22	127	155	207	201
10	9	24	114	166	198	195
12	8	19	105	164	198	196
14	10	20	108	176	206	204
16	7	19	98	163	206	206

The activated carboxyl groups of the amino-acids should take part in the synthesis of peptides. These activated carboxyl groups are capable of reacting with hydroxylamine giving rise to hydroxamic acid[2,3]. Like hydroxylamine, the amino-group of the amino-acid esters possesses a marked reactive capacity.

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Appearance of a Phosphorus Compound in Platelet-rich Plasma on Clotting

Previous experiments have shown that when clotting begins in human plasma containing platelets ('platelet-rich plasma'), adenosine triphosphate rapidly disappears from platelets with little or none of it appearing in the serum[1]. Other experiments suggested that in such plasma a phospholipoprotein is formed which is later broken down, and that this may be plasma thromboplastin[2].

Under the conditions used in those experiments fibrin appeared 5–10 min. after citrated plasma was recalcified. Since then a technique has been developed which leads to the formation of the clot within 2 min. With this technique the activity of thromboplastin in plasma reaches its maximum within 5 min. During that time there is not only a considerable breakdown of platelet adenosine triphosphate but also the appearance of a water-soluble phosphorus compound. This compound is the product of the breakdown of either phospholipid or phosphoprotein in the plasma.

To demonstrate this we made use of blood obtained from patients suffering from polycythæmia vera. The patients were being treated with phosphorus-32; some of this was incorporated into their plasma phospholipids and phosphoproteins which became radioactive. We observed the fate of this radioactivity during clotting. A representative experiment was as follows:

A male patient aged seventy-two was given 5 mc. of phosphorus-32 intravenously. After 48 hr., 200 ml. of blood was obtained from an arm vein and mixed with 4 ml. of 19 per cent (w/v) sodium citrate. The blood was centrifuged at 1,500*g* and 0–1° C. for 20 min. The plasma was removed and centrifuged at 22,000*g* for 15 min. to sediment the platelets. The supernatant platelet-free plasma (40 ml.) was dialysed at about 4° C., first against 3 l. Krebs–Ringer phosphate solution for 2 hr., and then for 18 hr. against 3 l. Krebs–Ringer bicarbonate solution modified so as to contain no phosphorus[3] and no glucose. The reason for dialysing against the phosphate solution was to reduce the specific activity of exchangeable phosphorus, and against the bicarbonate solution to reduce the concentrations of water-soluble phosphorus compounds in the plasma. After dialysis the concentration of inorganic phosphorus in plasma was 6·0 μgm./ml. and its specific activity was 0·6 counts/min. μgm. The specific activity of the plasma phospholipids was 14·7 and that of the plasma phosphoproteins 10·7 counts/min. μgm. phosphorus.

Samples (5 ml.) of dialysed plasma were incubated at 37° C. in glass tubes, the inner walls of which had been roughened by grinding. Platelets obtained from a healthy person were mixed with the plasma and 0·125 ml. *M* calcium chloride was added to each sample. The activity of thromboplastin was assayed at intervals of a few minutes. After 0, 1, 2, 4, 8 and 16 min., 1 ml. of 60 per cent (w/v) trichloracetic acid was added to a tube and thoroughly mixed with the clotting plasma. The tubes were cooled in ice and centrifuged at 0° C. for 5 min. at 22,000*g*. The clear supernatant solutions were decanted and retained. The precipitates were re-extracted with 5 ml. 10 per cent trichloracetic acid and the extracts were added to the first supernatants. The solutions were analysed for adenosine triphosphate by the firefly method[3]; and for inorganic phosphorus, organic phosphorus set free by *N* hydrochloric acid in 10 min. at 100° C. (10 min. phosphorus), and total phosphorus by the method of Berenblum and Chain[4]. The radioactivity of the phosphorus fractions was determined and expressed as counts/min. μgm. phosphorus.

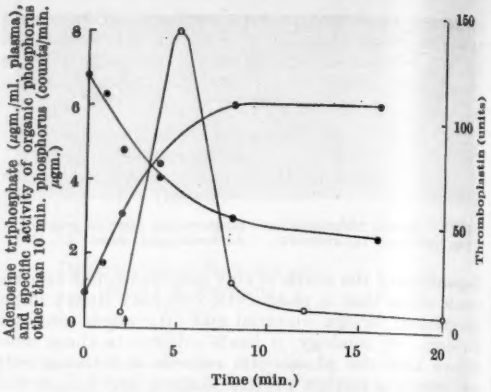

Fig. 1. Changes in the concentration of thromboplastin (○) and of adenosine triphosphate (●), and in the specific activity of organic phosphorus other than 10 min. phosphorus (○), in platelet-rich plasma during clotting. Calcium chloride was added at 0 min., and the clot formed after 2·3 min. as shown by the arrow

The results are shown in Fig. 1. The activity of thromboplastin increased steeply after 2 min., reached a maximum after 5 min. and then decreased almost equally rapidly. Adenosine triphosphate began to disappear within the first minute after the addition of calcium, and continued to do so at a decreasing rate for 16 min. At the time when the activity of thromboplastin was maximal almost half of the adenosine triphosphate had gone.

Also within the first minute there was an increase in the radioactivity of the trichloracetic acid solutions. This radioactivity continued to increase for about 8 min. and then remained constant. It was accounted for by an increase in the specific activity of organic phosphorus other than 10 min. phosphorus, which rose from 0·95 to 6·03 c./min. μgm. phosphorus. Since only the phospholipids and phosphoproteins had specific activities higher than this, the radioactive organic phosphorus which appeared in the trichloracetic acid solution must have originated from one or the other.

Five other experiments of this kind gave similar results. It may be concluded that, as thromboplastin is formed in plasma during clotting, plasma phospholipid or plasma phosphoprotein is broken down with the liberation of an acid-soluble substance containing phosphorus.

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Broadening of the X-ray Diffraction Lines in Teeth affected by Fluorine

THE diffraction of X-rays in the case of teeth can be investigated by a modification of the standard X-ray powder method, by producing biophysical specimens in the form of wires of tooth material by the careful cutting and filing of suitable pieces of tooth material. A 9 cm. camera of the Van Arkel type with filtered copper radiation has been used in comparing the diffraction lines from two specimens of teeth (one from a male and one from a female) which had been extracted following decay.

One of the teeth described had been surface-treated by a fluorine dental treatment approximately eight years previously, while the natural age of both teeth was similar. Cutting and filing was carried out so as to produce specimens of identical sizes, and such that one side in each case consisted of undamaged enamel: the resulting diffraction photographs are shown in Fig. 1 and it is seen that apart from the progressive broadening and blurring of higher-order lines in one photograph (from the specimen affected by fluorine, *a*), the patterns are identical.

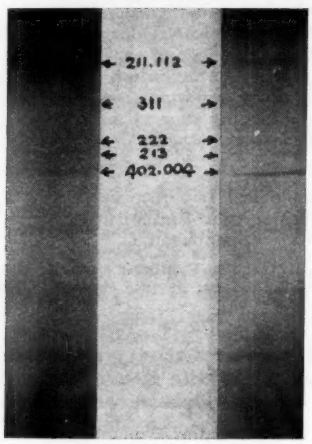

Fig. 1

The positions of the strongest lower-order diffractions were found to correspond with the hexagonal apatite form of crystal structure[1,2]. Since the teeth in their natural life must have experienced appreciable mechanical force and work of deformation, it is considered that a suggestion for the line-broadening based on normal stress/strain or grain size is less satisfactory than one arrived at by considering the variation of the surface composition within the cell-dimension limits of fluoro-apatite and chloro-apatite. This X-ray effect in hexagonal crystals has been previously described by one of us[3].

We are grateful to the Chemistry Department of the University of Sheffield for making available X-ray facilities.

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BIOLOGY

Triple Coitus in the Mealy Bug, *Planococcus citri* (Risso)

MALES of the mealy bug, *Planococcus citri*, do not feed throughout their nymphal stages of development nor after they emerge as adults. They are, nevertheless, highly active in mating during the few days of their short life as mature individuals. James[1] has observed that a single male may copulate with as many as 23 females in succession, and the average number of females fertilized by 13 individual males was 9·07. During my experience with mealy bugs cultured in the laboratory on potato, the observation has been made many times that two males will copulate simultaneously with one female while yet a third male may be attempting to do the same.

The fully winged males are quite sedentary, seldom fly, but crawl about on the potato in search of mature females. During the mating process, the females usually remain in the same spot at which they had previously settled in order to feed. It has not yet been possible to tell why a certain female in a group of equally old females attracts the males nor is it known how long after one mating the female remains attractive to males.

Simultaneous unions of two males with one female can be accomplished because of their relatively long abdomina. Usually the two males align themselves on the dorsal surface of the female; the abdomina and copulatory stylets then curve ventrally around the posterior limits of the female and both copulatory stylets and phalli penetrate the single vulva to the same extent. Both insertions are maintained by the males through considerable disturbance with a camel-hair brush, as is the case in pair matings. It is very likely, on the basis of this observation, that both copulations are genuine and that both mating acts are complete.

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Behaviour of Sacculinized Shore Crabs (*Carcinus maenas* Pennant)

For some years investigations on the ecology of the common shore crab, *Carcinus maenas*, have been carried out in inshore Danish waters (the Isefjord area, Zealand) and among other things the migrations of the species were studied. In contrast to the observations from British waters of Williamson[1] and others, it was observed that during the breeding season —which in the Isefjord comprises only May and June —the berried female crabs leave the littoral areas and hide in the more saline and deeper water (maximum depth 8–10 metres) until the larvæ are hatched. After this period they return to moult and copulate with the male crabs which stay all summer in shallow water (0–1·5 metres). The annual mean salinity of the Isefjord is 19·4 per mille.

It has now been found that sacculinized crabs (that is, both male and female crabs subjected to parasitic castration by *Sacculina*) carrying an externa (containing the gonads of the parasite) behave just like the normal berried females, that is, they hide in deep water. This seems to be normal for 'externa

crabs' in the Isefjord, since it was found every year during the investigation from its start in 1954. It should be emphasized that the externa stage in the Isefjord normally appears in summer and is sexually ripe in the autumn. The observations are based on material comprising many hundred infested shore crabs.

As the early stage of parasitization is visible externally only in male crabs owing to the more-or-less pronounced parasitic feminization of the male phenotype, only males have been used in the following. For practical reasons the cycle of the parasite is here divided into five stages of development (Fig. 1): (*a*) crabs containing the interna stage only, noticeable by the feminization; (*b*) crabs with the externa just developed, 2–4 mm. broad; (*c*) crabs with an externa of medium size, 5–10 mm.; (*d*) crabs with sexually ripe externa, 11–20 mm.; and (*e*) crabs showing the hole after losing the externa; infection probably stopped. As seen in Fig. 1 only stages (*a*) and (*e*), namely, crabs exhibiting the beginning and the final phase of the parasite, are common in shallow water. The tendency of the 'externa crabs' to avoid the shore areas seems to be intensified with the ripening of the externa. Catches with traps in deeper water have confirmed this picture and shown the presence there of a rather high percentage of infested crabs with externa. It must be borne in mind, however, that the duration of the stay of the 'externa crabs' in deep water considerably exceeds that of the normal berried females, sometimes amounting to about a year or even more. This means that while the stages (*a*) to (*d*) of Fig. 1 represent the parasite in crabs one year old (infested in the autumn just after their metamorphosis in 1953), the final stage (*e*) of the parasite is present in crabs metamorphosed before 1953.

Broekhuysen[2] found that normal berried female crabs often show a characteristic behaviour of "egg cleaning and airing", consisting of piercing of the egg-mass by the pereiopods, followed by periodical flapping of the abdomen. A completely similar behaviour has now been observed in infested crabs of both sexes provided with an externa. In several cases studied in aquaria these characteristic movements were observed as soon as the externa appeared, and they seem to be intimately connected with the presence of an externa. In male crabs of maximal size and without any visible feminization at all the behaviour was also observable when the small externa broke through. This behaviour was shown to be highly affected by the oxygen tension of the water, low oxygen tensions accelerating the characteristic movements in a most conspicuous way.

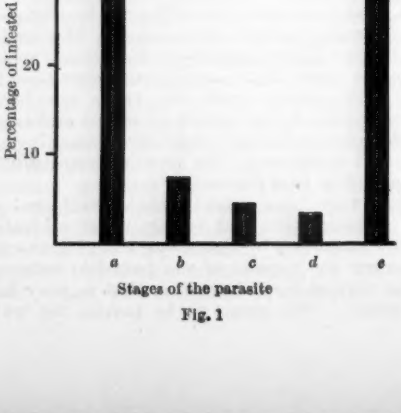

Fig. 1

The influence on behaviour caused by the disappearance of the externa shown by the field investigations was confirmed by observations in aquaria. In some cases where the externa had stopped producing its sexual products, and a slight decaying of the externa had begun, the behaviour mentioned above disappeared, and in several cases the host crab even tore the externa, and in one case was seen to be eating the remnants of the externa.

These observations suggest that only a living externa is able to promote the special behaviour seen in sacculinized crabs. It cannot, therefore, be regarded as a simple tactile response to the presence of a foreign object under the abdomen. I have made a few preliminary experiments with artificial externae fastened to the abdomen, and, though still inconclusive, they point in the same direction.

Without entering into a discussion of the various theories of the influence of the Rhizocephalous parasite on the host, I think that the behaviour of the parasitized crabs reported here may probably be interpreted as being due to a hormonal feminizing effect of the externa stage.

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Histolytic Activity in Seasonal Hypertrophy of the Reproductive Organs of *Hyla aurea*

While not yet reported in other frogs or in *Hyla aurea* elsewhere, hernia occurs in 0·3 per cent of this species taken in the Wellington district. The hernias seen involve various portions of the reproductive system, and are related to seasonal prebreeding organ hypertrophy. In one specimen, the uterine portion of the oviduct was ruptured through the body wall between the lateral face of the ilium and the origin of m. gluteus, to form a large mass in the dorsal lymph space. This appeared to be hernia by dissection along an anatomical pathway by pressure atrophy, as also in a second example where part of the testicular fat-body ruptured into the dorsal lymph-space between the body-wall muscles and the muscles on the lateral aspect of the ilium. A portion of the posterior lobe of the right ovary in another frog had perforated the mm. abdominis transversus and obliquus internus. This also was interpreted as based on pressure atrophy[1].

Establishment of a pathway by pressure atrophy was quite impossible in a case where an abnormally enlarged, elongated process of the right fat-body in a female had perforated the linea alba and formed a hernial mass in the ventral subcutaneous lymph-space shortly posterior to the xiphisternum. There is an absence of adhesions. It is beyond probability

that a fat-body freely suspended from the dorsal aspect of the abdominal cavity could have induced atrophy by pressure in a structure such as the linea alba. Sudden mechanical pressure, such as a blow, a preformed embryonic pathway, failure of body-wall structure through postural gravity effects, interference with the vascular supply and other recognized causes of rupture likewise provided no satisfactory explanation for this case. Accordingly, it was suggested by way of hypothesis[2] that at the surface of a rapidly growing fat-body there are the mechanism of hyperplasia and hypertrophy and also a histolytic mechanism. The latter process, if induced by a substance transferable from the tip of the fat-body to the peritoneum and tissues of the linea alba, would provide a probable explanation for the establishment of the initial pathway for the hernia.

A further example in which the posterior lobe of the left ovary of a gravid adult frog extended into the left paravesical space, and, without adhesions, passed through the walls of the bladder to enter the right paravesical space and then the right femoral lymph-space where it expanded to normal size, gives further support to the above suggestion, especially since the foramen in the bladder is only 3·0 mm. in diameter, thus indicating that the bladder was perforated originally by the tip of the lobe of the ovary. The two walls of the bladder are fused around the margin of the perforation, and the lumen of the bladder closed off from the coelom. The posterior lobe of the right ovary had also ruptured into the femoral lymph-space, probably following the path established by the lobe of the left ovary.

The existence in the tadpole of histolytic processes is recognized in the tissue reductions and modifications during metamorphosis, and in the seasonal reduction of the reproductive organs following breeding. The results above indicate that a histolytic process is present during the growth and elaboration of the reproductive organs prior to breeding. It may be suggested that this process is responsible during that time for the breakdown of tissues which might otherwise cause mechanical difficulties during hyperplasia and hypertrophy of the adipose tissue in the fat-body and of the germinal tissue in the ovary. It may also assist in ovulation.

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A Monogenetic Trematode New to the British Fauna

In the course of a survey of the parasite fauna of gadoid fishes in the northern North Sea, I have examined 28 cod (*Gadus callarias* L.) from various localities along the east coast of Scotland in the second half of 1958. The fish were all less than one year old and ranged in size from 12·4 to 18·6 cm. Three of these fish were infested by a species of *Gyrodactylus* (Trematoda : Monogenea), not hitherto recorded from British waters. The parasites were attached to the gills (rakers, bars and filaments) and within the buccal cavity of their hosts. One cod was found to harbour five specimens of *Gyrodactylus* in its nostrils—a somewhat unusual habitat for this trematode genus. The numbers of parasites varied from host to host, the lowest being 6 and the highest 197 specimens. All three infested fish were caught relatively near the shore : one was taken in the Firth of Forth, 5 miles east of May Island, and two about 15 miles south-east of Stonehaven, at a depth between 55 and 68 m.

The parasites were identified by Dr. Göran Malmberg of Zootomiska Institutet, Stockholm, as *Gyrodactylus callariatis*[1]. The species was described by Dr. Malmberg from cod taken in Nämdö, near Stockholm. The dimensions of the fresh specimens are as follow :

Total length	0·42–0·70 mm.
Body width	0·09–0·18 mm.
Opisthaptor length	0·08–0·12 mm.
Opisthaptor width	0·11–0·15 mm.

The anchoring apparatus of the species is distinguished by a dorsal bar with a central process pointing posteriorly. Its ventral bar is large and provided with wide antero-lateral processes. The membrane of the ventral bar is grooved and wide at the base. The marginal hooks are long and slender.

G. callariatis differs significantly from *G. marinus*, another species of the genus found on cod in the Barents Sea and the northern Pacific[2].

The genus *Gyrodactylus* contains relatively few marine species. They infest mainly young fish in coastal areas. Like some other monogenetic trematodes, *G. callariatis* appears to be a 'childhood' parasite[3], which might be the reason why it has not so far been discovered in British waters. Young stages of fish are only infrequently used for parasitological examinations.

I have also found another species of *Gyrodactylus* on whiting, *Gadus merlangus* L., in the same area. The specimens of this parasite are at present in Dr. Malmberg's hands.

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A Diagnostic Reaction of *Desulphovibrio desulphuricans*

The sulphate-reducing bacteria at present available in pure culture are *Desulphovibrio desulphuricans*, its *aestuarii* variant[1], the thermophilic *Clostridium nigrificans* (earlier known as *D. thermodesulphuricans*[2]) and the new species *D. orientis*[3]. The species *D. rubentschickii* and its variant *anomalous*, able to utilize acetate and/or butyrate[4], have so far defied re-isolation.

Cl. nigrificans is readily distinguished from the other species by its thermophilic habit. *D. orientis* shows broad differences in appearance and motility from the *desulphuricans* pair, but is mainly distinguished by its multiple flagellation and ability occasionally to form spores, and neither of these features is technically very satisfactory for rapid diagnosis. A third distinguishing test has been devised making use of the absence of desulphoviridin[5] from *D. orientis*. The pigment desulphoviridin dissociates in alkaline solution to yield a photo-

sensitive chromophoric group having a strong red fluorescence in ultra-violet light at 365 mμ.

The following procedure distinguishes pure cultures of *D. desulphuricans* and its *aestuarii* variant from *D. orientis*: a fully grown culture in 10 ml. of medium *C* of Butlin, Adams and Thomas[6] was centrifuged and the cells resuspended in 1 ml. water (final cell density 1·5–3 mgm. dry wt./ml.). One drop of 20 per cent sodium hydroxide was added and the suspension inspected at once in light at 365 mμ. Twenty strains of the *desulphuricans* group were tested and showed a brilliant red fluorescence; three strains of *D. orientis* did not, nor did six strains of *Cl. nigrificans*. Large amounts of ferric sulphide in the culture interfere, but may be removed by coarse filtration.

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Separation of Specific and Non-Specific Effects of Chemicals on Plants

In working with the effects of chemicals on plants, it is often difficult to determine which of the effects obtained is specific to the chemical applied. For example, 2,4-dichlorophenoxyacetic acid (2,4-D) has been shown to cause numerous effects on plants. A recent review by Woodford *et al.*[1] discusses this subject in detail. It has been shown that 2,4-dichlorophenoxyacetic acid causes varied tissue changes, affects phosphorus metabolism, increases respiration, decreases photosynthesis and, in general, affects a great many functions of the plant.

Although it is true that these effects do occur on plants, it is by no means certain which, if any, of these reactions is of primary importance, and which are secondary. The living plant represents a dynamic, balanced system, and any change which affects one function of the plant will necessarily affect a great many others. Some of these changes will be associated with any type of killing mechanism; others will be specific. The data presented in many of the reports in the literature are not sufficient to establish this point. Frequently, there is no mention of whether there has been gross damage to the experimental plants, and the reader may suspect that the changes reported are simply those characteristic of damaged or dying plants.

One way of tackling the problem of which changes are of a non-specific nature is to use a control which has been allowed to die without outside chemical influence. We have attempted to do this in our experiment by digging up some of the plants, washing off the roots, and letting them lie on the greenhouse bench for the duration of the experiment. A similar technique was used by Loustalot *et al.*[2] in field experiments.

Bean plants (*Phaseolus vulgaris* L.) were grown in the greenhouse in a mixture of sand and peat soil until they were three weeks old. The beans were then selected for uniformity and treated. Foliage sprays of 1, 2, and 4 lb. per acre acid-equivalent of 2,4-dichlorophenoxyacetic acid (amine salt in water solution) were applied. There were four replicates of each treatment, and the plots were completely randomized in the greenhouse. The roots were harvested 1, 4, 11 and 18 days after treatment. Epinastic responses in the young leaves were visible on the first day after all treatments. The plants were dead in the 4 lb. treatment in 18 days. At this time, plants treated with 2 lb./acre were very stunted and malformed and those treated with 1 lb./acre apparently were recovering. Total protein content (alcohol-insoluble nitrogen) free amino-acid nitrogen, and individual amino-acids were determined as reported elsewhere[3,4]. A brief summary of the results is given in Tables 1 and 2. The trends for individual amino-acids were similar to those for total free amino-nitrogen. A fuller account of these results is in preparation.

Table 1. Changes of Protein in Treated Bean Roots (mgm. Alcohol Insoluble Nitrogen per Plant)

2,4-D per acre (lb.)	Days after treatment 1	4	18
0 (untreated)	2·64	2·54	2·80
1	2·90	2·58	2·51
2	2·71	—	1·60
4	2·51	2·30	1·30
0 (uprooted)	2·58	1·92	1·91

Table 2. Changes in Free Amino Nitrogen in Treated Bean Roots (mgm. per Plant)

2,4-D per acre (lb.)	Days after treatment 1	4	18
0 (untreated)	0·109	0·075	0·075
1	0·111	0·104	0·057
2	0·095	—	0·039
4	0·102	0·077	0·029
0 (uprooted)	0·114	0·090	0·006

Although pronounced changes occurred in the proteins of the plants following 2,4-dichlorophenoxyacetic acid treatment, and these changes appeared superficially to be correlated with the amount of 2,4-dichlorophenoxyacetic acid applied, it is obvious that equally drastic changes occurred in the plants that were uprooted and not treated with 2,4-dichlorophenoxyacetic acid. It appears, therefore, that these changes in the proteins and the amino-acids occurred as a result of damage or death, and not directly as a result of 2,4-dichlorophenoxyacetic acid treatment *per se*. Our results suggest, therefore, that the effect of 2,4-dichlorophenoxyacetic acid on protein metabolism is of secondary importance. They also emphasize the value of this type of control. Without this control, it would have been possible to draw exactly opposite and erroneous conclusions.

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Effect of Boron Supply on the Sugars, Soluble in 80 per cent Ethanol, in Flax Seedlings

FLAX plants (*Linum usitatissimum* var. Ventnor) were grown in nutrient cultures supplied with increasing concentrations of boron. The methods were such that an addition of 0·001 p.p.m. boron to the basal medium produced a large growth response. After four weeks the plants were harvested and weighed (Fig. 1). The 0 p.p.m. boron plants grew very little throughout the four weeks; both these and the 0·001 p.p.m. boron plants showed typical deficiency symptoms in stems and roots.

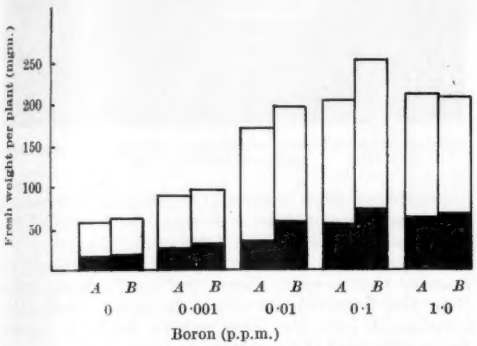

Fig. 1. Fresh weight of flax plants grown at increasing levels of boron supply. White, tops; black, roots

The plants of each treatment (which was duplicated) were divided into stem tips, the remainder of stem and leaves, and roots. These tissues were extracted with 85 per cent ethanol. Extracts, usually each equivalent to 40 mgm. fresh weight, were spotted on to No. 3 Whatman paper, and the chromatograms were eluted with a pyridine/ethyl acetate/water (80 : 20 : 10). Two chromatograms were run for each set of extracts. One was developed with silver nitrate and ethanolic sodium hydroxide; from the other the portions of paper corresponding to the sucrose, glucose and fructose spots were eluted and the sugars estimated by the method of Wager[1].

Sucrose, glucose and fructose were the principal sugars detected. Qualitative examination of the chromatogram (Fig. 2) showed no evidence that the stem tips and roots of boron-deficient plants were carbohydrate-deficient. The results of the quantitative analyses confirm this (Table 1).

Table 1. THE EFFECT OF BORON ON THE DISTRIBUTION OF SUGARS IN FLAX

P.p.m. boron in culture medium		0*	0·001*	0·01	0·1	1·0
		Sugar concentration (mgm./gm. fresh weight)				
Stem tips	Sucrose	0·90	1·85	2·18	2·00	1·57
	Glucose	3·00	2·90	1·55	1·10	1·14
	Fructose	1·98	2·48	0·67	0·32	0·39
Remainder of stem and leaves	Sucrose	0·41	0·13	0·37	0·41	0·38
	Glucose	1·75	1·40	0·73	1·40	1·00
	Fructose	1·00	0·85	0·79	0·73	0·30
Roots	Sucrose	None detected				
	Glucose	1·60	1·41	0·95	0·60	0·61
	Fructose	1·54	1·18	0·57	0·54	0·19

* Plants showing boron-deficiency symptoms.

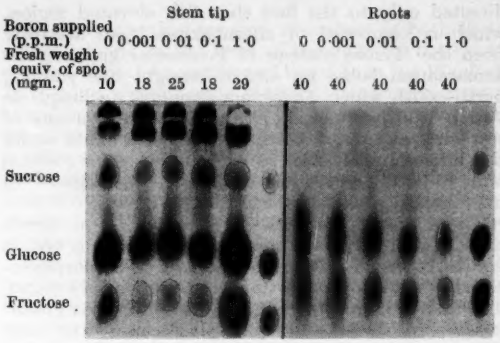
Stem tip
Roots
Boron supplied (p.p.m.) 0 0·001 0·01 0·1 1·0 0 0·001 0·01 0·1 1·0
Fresh weight equiv. of spot (mgm.) 10 18 25 18 29 40 40 40 40 40
Sucrose
Glucose
Fructose

Fig. 2. The sugars in the stem tips and roots of flax plants grown at increasing levels of boron supply

Boron deficiency appears to depress the sucrose, but not the fructose or glucose content of flax stem tips. The remainder of the stems and leaves of boron-deficient plants in general contain more of the three sugars, expressed on the fresh weight basis, than normal plants, while in flax roots boron deficiency results in the accumulation of glucose and fructose.

These results do not support the hypothesis[2,3] that the cessation of growth in boron-deficient plants may be attributed to a carbohydrate deficiency in shoot tips and roots. It has further been demonstrated in this laboratory that excised flax roots grown in a specially purified sterile medium, which included 4 per cent sucrose, ceased to grow after 48 hr. in the absence of boron.

I wish to thank Dr. K. S. Rowan for advice on matters of technique.

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GEOLOGY and PHYSIOGRAPHY

Trap-Shotten Rock from the Biligirirangan Hills, Mysore State, India

CHARNOCKITIC rocks have been developed over a wide area in the southern part of the State of Mysore in India. The typical charnockites are found in isolated patches of varying dimensions. The largest of these occurrences is in the Biligirirangan Hills, where a fairly continuous mass of charnockite extending more than 25 miles forms this mountainous tract which lies between 11° 40′ and 12° N. In this region peaks of more than 5,000 ft. are common on the ranges, which generally trend in a north to south direction.

For the purposes of this communication, it is not necessary to describe the petrography or the rock associations of this interesting area. Attention is

directed only to the fact that this elevated region, which is composed of charnockites, rises abruptly from the Mysore plateau of Peninsular gneisses, the demarcation being an almost straight line running north–south which corresponds roughly to longitude 77° 10′ E. This junction is characterized by a zone of trap-shotten material, which when examined under the microscope is seen to contain beautiful rosettes and radiating, parallel, or matted aggregates of microlites and skeleton crystals.

The trap-shotten rock is composed of a brown matrix with abundant minute specks of iron ore, in which fragments of charnockite as well as porphyroclasts of feldspar, quartz, and hypersthene are found. The quartzes are optically strained and often granulated. In the case of the plagioclases, the twin lamellæ are generally bent and sometimes obliterated. The borders of these xenoclasts are corroded and frequently embayed.

There is no glass at present, but the brown matrix shows signs of patchy devitrification being full of

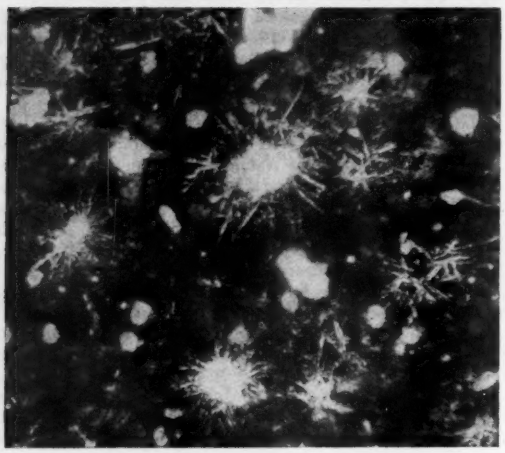

Fig. 1. Stellate aggregates of oligoclase in trap-shotten rock. The embayed quartz porphyroclasts do not serve as nuclei for the outgrowths of skeleton crystals. (× 40)

Fig. 2. Skeleton crystals of oligoclase in a devitrified irresolvable matrix. (× 160)

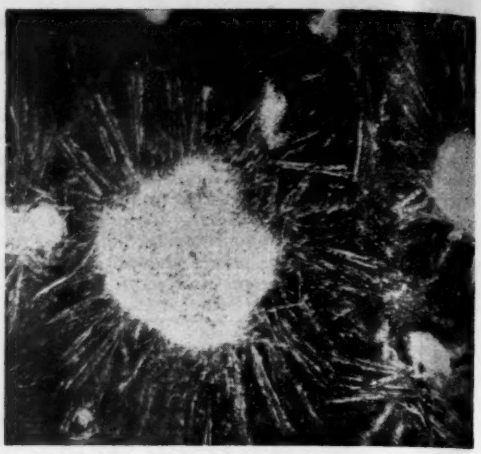

Fig. 3. Skeleton crystals of oligoclase radiating from plagioclase porphyroclasts. (× 120)

microlites of some mineral (? orthorhombic pyroxene) which are arranged as in a comb with parallel bars developed on either side of the central axis.

The junction between the pseudotachylyte and the country rock is quite sharp, the border being darker than the brownish interior. In some places it has penetrated into the charnockitic rock or engulfed fragments near the contact.

The most interesting feature of the pseudotachylyte is the occurrence of numerous star-shaped aggregates of skeleton crystals of feldspar (Fig. 1). The individuals are long and ladder-like, generally hollow and swallow-tailed (Fig. 2). They are also arranged in radiating patterns around porphyroclasts of plagioclase (Fig. 3). It is significant that the quartz fragments do not serve as nuclei for these outgrowths.

The extinction angle of these crystals is nearly straight, and the refractive index slightly higher than that of Canada balsam. These correspond to the characters of an oligoclase of composition about $Ab_{75}An_{25}$.

The temperature at which rocks can be fused by frictional heat has often been discussed. Shand[1], in his classification of pseudotachylytes, has listed Indian localities under "black rocks composed of crushed material without recrystallization or any evidence of elevated temperature", and doubtfully under "black rocks which bore evidence of high temperature approaching the melting points of some of the constituents, and with beginnings of crystallization". This is probably because of Holland's observation[2] that "the black material has essentially the microscopic structure of an indurated dust, never that of a rock cooled from fusion".

The example of trap-shotten rock from Mysore State described in this communication indicates that the temperature produced by friction was high enough to melt and cause the recrystallization of oligoclase in radiating aggregates.

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Heavy Minerals in Certain Old Red Sandstone and Silurian Limestones of Monmouth

THE Wenlock Limestone outcrops intermittently within the inlier of Silurian rocks situated between Usk and Pontypool, and the 'Cornstones'[1] as discontinuous bands within the Old Red Sandstone of Monmouth. Samples of both limestones were crushed, dispersed, and particles with a diameter greater than 0·2 mm. removed by wet sieving, and those with a diameter less than 0·02 mm. by decantation. The residue corresponding to fine sand contains the bulk of the heavy minerals which were separated in bromoform, identified, and their relative proportions determined by microscopic counts which have been combined in Table 1.

Table 1

	Old Red Sandstone Cornstones (per cent)	Silurian Wenlock Limestone (per cent)
Zircon	56	47
Tourmaline	13	15
Rutile	11	16
Garnet	7	11
Monazite	0	6
Epidote	3	5
Enstatite	4	0
Hypersthene	2	0
Fluorite	3	0
Anatase	1	0

Prismatic zircon grains with rounded terminations constitute the bulk of the heavy mineral assemblage in both limestones, mostly of dusky hue in the Wenlock Limestone and colourless within the Cornstones. Zircons within the latter show greater variety, some showing marked red staining and containing many inclusions which, in a few grains, are sufficiently abundant to render the grain almost opaque. Pink and pleochroic brown zircons may also occur. Tourmaline prisms with rounded rhombohedral terminations, pleochroic in all shades from green to brown, are moderately abundant in both limestones. The Cornstones contain, in addition, some well-worn rounded flakes. Also moderately abundant in both limestones are rutile grains, chiefly amber, which may be prismatic with rounded or irregular terminations or of a well-rolled character. A few grains in the Wenlock Limestone are foxy-red and in the Cornstones grey. Garnets, wine-red in colour and with pitted surfaces and polygonal outline, are more numerous within the Wenlock Limestone than in the Cornstones, where most garnets are colourless, contain many inclusions, and display an intricate rectangular outline presumably due to the dodecahedral cleavage.

Some yellowish, egg-shaped grains of monazite occur only in the Wenlock Limestone. Epidote prisms with rounded or irregular terminations are mostly of the orthorhombic zoisite variety in the Wenlock Limestone and monoclinic clinozoisite variety in the Cornstones. A very few grains of yellow anatase and fluorite occur only within the Cornstones. A characteristic feature of this limestone is the presence of pyroxene, either as dusky enstatite prisms or as pleochroic green and pinkish hypersthene prisms. One grain, too altered to allow accurate identification, may possibly be augite.

Slightly pleochroic, angular, green plates of chlorite are reasonably abundant in both limestones, and may be somewhat corroded at the margins within the Cornstones. Biotite is relatively uncommon. The opaque iron oxides are very abundant in both limestones, chiefly in the form of hæmatite in the Cornstones and both hæmatite and limonite in the Wenlock Limestone, with ilmenite of lesser quantitative importance in either case. Detrital quartz showing pronounced undulose extinction and streams of inclusions is also abundant. The feldspars consist chiefly of moderately fresh oligoclase, andesine and orthoclase. Anorthite grains are also quite numerous in the Cornstones. All the minerals show at least slight evidence of abrasion and are therefore detrital in origin.

The Wenlock Limestone is inter-stratified with argillaceous rocks which are more characteristic of relatively deeper depositional waters. The Cornstones are interbedded with marls and arenaceous rocks the presence of which suggests shallower water conditions, Heard and Davies suggesting brackish water lagoons with rapidly changing conditions. The slightly greater variety of mineral species within the assemblage of the Cornstones is consistent with a shallower water depositional environment. The mineral assemblage of the latter limestone shows an expected close similarity with that of the other Old Red Sandstone strata described by Heard and Davies. There is, however, the exceptional occurrence of pyroxene in the Cornstones. This mineral, less stable than other species such as zircon, rutile and tourmaline, appears to have been preserved within the limestone. This feature of the preservation of certain less stable mineral species in limestone interbedded with sandstones and shales has been noticed by Smithson in the Jurassic rocks of Yorkshire[2].

C. B. CRAMPTON

Soil Survey of England and Wales,
Rothamsted Experimental Station,
Harpenden,
Herts.
Jan. 6.

[1] Heard, A., and Davies, R., *Quart. J. Geol. Soc.*, **80**, 489 (1924).
[2] Milner, H. B., "Sedimentary Petrography", third edit., 393 (Murby London, 1952).

Stability of Stone Polygons in North Wales

THIS communication describes certain preliminary observations made on stone polygons in Snowdonia during the summer of 1957, observations which appear to reveal the impermanent character of these structures. The polygon area has been briefly described by Pearsall[1]; it consists of several connected flat expanses of bare detritus, formed from the erosion of the Juncetum squarrosi occupying the broad ridge between Carnedd Llywelyn and Foel Grach summits in the Carneddau at 915–945 m. The area was casually examined several times during the summer of 1956, but no polygons were observed, the detritus being unsorted. In the course of field work during the first week of July 1957 well-defined stone polygons were noticed over the whole area (Fig. 1); each polygon was 45–60 cm. in diameter, with a centre of fine gravelly detritus and a rim, 10–15 cm. wide, of coarse stone (3–10 cm.); these coarse stones extended downwards for 10–15 cm., finally merging into a matrix continuous with the polygon centres. Ten days later, after predominantly fine weather but with a few days of rain with a blustery north-east wind, it was noticed that a large proportion of the polygons had, by apparent obliteration of the cross-connexions, been converted into stone stripes 2–4 m. long, orient-

ated more or less at right angles to the direction of the prevailing wind (Fig. 2). For much of the remainder of July 1957 the weather was wet, with more or less permanent low cloud. On July 15 there was little change in the polygons. On July 30, however, after a fortnight of heavy rain and strong winds, a large number of the polygons and stripes had been obliterated or were in process of obliteration. On September 3 one of the areas was almost completely unsorted, and many of the stripes on the other areas were indistinct. Polygons were very rare, and the stripes had markedly elongated, extending for many metres without interruption. In July 1958, the next opportunity for a further examination, the area exhibited little change, except qualitatively in that the stone stripes appeared far less elongated.

It has been supposed that the balance between polygons and stripes is determined by slope, polygons being developed only on flat ground, elongated polygons on ground with a slope of 2–7 deg., and stripes on ground with a slope of 10 deg. or more[2]. On the area described above there is an imperceptible slope, of 1–1·5 deg. east–west, down which the stripes are orientated, but the occurrence of polygons among the stripes cannot be related to any localized flat areas. It is interesting to note that patches within the polygon area with a developing plant cover (of *Rhacomitrium lanuginosum*) have completely unsorted detritus, suggesting a recent origin for the polygons, and that areas with partly obliterated polygons are characteristically flat.

It has only recently been realized how rapid the processes of change in stone polygon and stripe areas can be. Undoubtedly many of these structures are exceedingly stable: thus photographs of polygons in the French Alps taken in 1934, 1942 and 1947 superposed exactly[2]. On the other hand, Michaud and Cailleux destroyed stone stripes in the same region in August 1947, and they had been reformed in August 1949 continuous with the undisturbed stripes[3]. The same authors marked stones in six polygons, and after two years there had been appreciable change in two of them: the stones had moved up to 10 cm. on the surface, and some of them were found buried at a depth of 13 cm. Cailleux and Taylor[2] also record polygons and stripes formed on moraines abandoned four years previously.

Thus the observations in North Wales are not unique, though the rapidity of change appears unparalleled. The winter of 1956–57 in North Wales

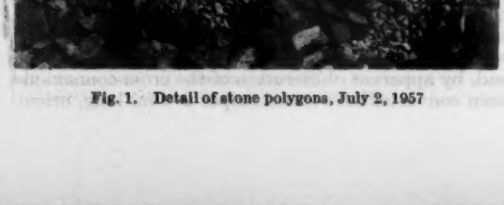

Fig. 1. Detail of stone polygons, July 2, 1957

Fig. 2. General view of elongated polygons, July 15, 1957

was marked by intense cold with only minimal snow cover—ideal conditions for polygon formation (since a covering of snow reduces the depth of penetration of frost into the soil by some 2–2½ times, and delays thawing by the same factor). In normal winters the ridge between Carnedd Llywelyn and Foel Grach has a good depth of snow. The rapid changes during July 1957 appear to be related to the unusually heavy rainfall and high winds; the polygon area has a high water-table, and after heavy rain this may locally reach the surface. On July 30, 1957, the mean depth of the water-table below the polygons was 10–12 cm., but a few were still saturated throughout. It may be that during heavy rain the finer detritus becomes almost liquid and flows among the intervening larger stones, while under the influence of strong winds there may be considerable movement of these larger stones also. The observations suggest that on an area with a slope barely sufficient for 'elongated polygon' formation, cryoturbatic processes may result in the formation of more or less isodiametric polygons, but that afterwards rain and wind may accentuate the effect of the slope and result in a transformation into elongated polygons. The extremely potent erosive action of wind-driven rain at high altitudes is testified in the vegetation throughout North Wales, and the combination of relatively mild winters, high rainfall, and frequent strong winds must certainly be inimical to the continued survival of any polygon and stripe systems.

These observations are necessarily incomplete, since the desirability of a more quantitative approach was not realized until too late, but it is believed that they are of sufficient interest to merit recording in this incomplete form.

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London, S.W.7.
Dec. 10.

[1] Pearsall, W. H., "Mountains and Moorlands" (Collins, 1950).
[2] Cailleux, A., and Taylor, G., "Actualités scientifiques et industrielles 1203. Expéditions Polaires françaises IV. Cryopédologie, études des sols gelées" (Hermann et Cie., Paris, 1954).
[3] Michaud, J., and Cailleux, A., *C.R. Acad. Sci., Paris*, 230, 314 (1950).

FORTHCOMING EVENTS

*(Meetings marked with an asterisk * are open to the public)*

Monday, February 16

SOCIETY OF CHEMICAL INDUSTRY (joint meeting of the SURFACE ACTIVITY GROUP and the PESTICIDES GROUP, at 14 Belgrave Square, London, S.W.1), at 5.30 p.m.—Dr. G. S. Hartley: "The Role of Surface Active Substances in the Application of Pesticides".

UNIVERSITY OF LONDON INSTITUTE OF EDUCATION (in the Assembly Hall, Malet Street, London, W.C.1), at 5.30 p.m.—Prof. E. A. Peel: "Behaviourism and Verbal Learning".*

ROYAL GEOGRAPHICAL SOCIETY (at 1 Kensington Gore, London, S.W.7), at 8.30 p.m.—Group-Captain D. St. C. Smallwood, O.B.E.: "Mongolia, 1958".

Monday, February 16—Tuesday, February 17

INSTITUTION OF ELECTRICAL ENGINEERS, MEASUREMENT AND CONTROL SECTION (at Savoy Place, London, W.C.2)—Specialist Discussion Meetings on "New Digital-Computer Techniques".

Tuesday, February 17

UNIVERSITY COLLEGE (in the Anatomy Theatre, Gower Street, London, W.C.1), at 1.15 p.m.—Dr. A. D. Blest: "The Evolutionary Origins of Distance Communication by Honey-Bees".*

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS (at 6 Buckingham Gate, London, S.W.1), at 2.15 p.m.—Mr. P. G. Finn-Kelcey: "The Application of Electricity to Agriculture".

LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE (at Houghton Street, Aldwych, London, W.C.2), at 5 p.m.—Dr. G. Tugendhat: "The Economics of Energy".* (Further lectures on February 23 and March 3.)

INSTITUTION OF MECHANICAL ENGINEERS, HYDRAULICS GROUP (at 1 Birdcage Walk, Westminster, London, S.W.1), at 6 p.m.—Discussion on "The Pumping of Liquids of Unusual Viscosity, Volatility, or Solid or Gas Content".

BRITISH COMPUTER SOCIETY (at the Northampton College of Advanced Technology, St. John Street, London, E.C.1), at 6.15 p.m.—Mr. R. Neate: "The Simulation of Melting Shop Operations on a Computer".

PLASTICS INSTITUTE, LONDON AND DISTRICT SECTION (at the Wellcome Building, 183–193 Euston Road, London, N.W.1), at 6.30 p.m.—Dr. A. W. C. Taylor: "Sources of Raw Materials for the Plastics Industry".

SOCIETY OF CHEMICAL INDUSTRY, LONDON SECTION (at the Royal Empire Society, Northumberland Avenue, London, W.C.2), at 6.30 p.m.—Film Evening.

ROYAL AERONAUTICAL SOCIETY (at 4 Hamilton Place, London, W.1), at 7 p.m.—Mr. R. H. Woodall: "Engine Starting Systems".

Wednesday, February 18

ROYAL SOCIETY OF ARTS (at John Adam Street, Adelphi, London, W.C.2), at 2.30 p.m.—Prof. E. G. Richardson: "Rheology—the Science of Plastic Flow".

PHYSICAL SOCIETY, COLOUR GROUP (in the Small Physics Theatre, Imperial College, Imperial Institute Road, London, S.W.7), at 3.30 p.m.—Miss J. Cox: "Colour Vision Defects acquired in Diseases of the Eye"; Mr. M. Clowes: "Colour and the Stabilized Retinal Image"; Mr. I. M. Gibson: "Visual Mechanisms in a Cone Monochromat".

EUGENICS SOCIETY (at Manson House, 26 Portland Place, London, W.1), at 5 p.m.—Dr. Mary Stocks: "Reflexions on a Changing Class Structure"* (Galton Lecture).

ROYAL METEOROLOGICAL SOCIETY (at 49 Cromwell Road, London, S.W.7), at 5 p.m.—Mr. J. S. Sawyer: "The Temperature, Humidity and Cloud Near Fronts in the Middle and Upper Troposphere"; Mr. F. K. Ball: "Long Waves, Lee Waves and Gravity Waves"; Mr. B. J. Mason and Mr. J. Maybank: "Ice-Nucleating Properties of Some Natural Mineral Dusts".

ROYAL STATISTICAL SOCIETY (at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1), at 5.15 p.m.—Dr. P. Armitage: "The Comparison of Survival Curves".

INSTITUTION OF ELECTRICAL ENGINEERS, RADIO AND TELECOMMUNICATION SECTION (at Savoy Place, London, W.C.2), at 5.30 p.m.—Mr. C. N. Smyth and Mr. J. Sayers: "Ultrasonic Iconoscopes".

ROYAL INSTITUTE OF CHEMISTRY, LONDON SECTION (at King's College, Strand, London, W.C.2), at 6.30 p.m.—Dr. F. E. T. Kingman: "Chemical Aspects of Fire Prevention".

Thursday, February 19

ROYAL SOCIETY (at Burlington House, Piccadilly, London, W.1), at 4.30 p.m.—Sir Owen Wansbrough-Jones, K.B.E., C.B.: "Some Chemical Advances in the Ministry of Supply".

INSTITUTION OF MINING AND METALLURGY (at the Geological Society, Burlington House, Piccadilly, London, W.1), at 5 p.m.—Dr. J. S. Webb and Dr. J. S. Tooms: "Geochemical Drainage Reconnaissance for Copper in Northern Rhodesia".

LONDON MATHEMATICAL SOCIETY (at the Royal Astronomical Society, Burlington House, Piccadilly, London, W.1), at 5 p.m.—Dr. J. F. Wilkinson: "Rounding Errors in Algebraic Processes".

ROYAL AERONAUTICAL SOCIETY (at the Institution of Civil Engineers, Great George Street, London, S.W.1), at 6 p.m.—Mr. E. G. C. Burt: "Theoretical Studies of Guided Missile Systems".

SOCIETY OF CHEMICAL INDUSTRY, ROAD AND BUILDING MATERIALS GROUP (at 14 Belgrave Square, London, S.W.1), at 6 p.m.—Dr. S. H. Bell: "Paint and Paint Films as Chemical and Physical Structures".

INSTITUTION OF MECHANICAL ENGINEERS, GRADUATE'S SECTION (at 1 Birdcage Walk, Westminster, London, S.W.1), at 6.30 p.m.—Mr. T. N. Dewey and Mr. J. E. Stephenson: "Gyroscopes in Automatic Controls".

INSTITUTE OF BIOLOGY, LONDON BRANCH (at 41 Queen's Gate, London, S.W.7), at 7.30 p.m.—Dr. C. G. Butler: "The Social Organization of the Honey Bee Community".*

ROYAL SOCIETY OF TROPICAL MEDICINE AND HYGIENE (at Manson House, 26 Portland Place, London, W.1), at 7.30 p.m.—Prof. K. R. Hill: "Some Aspects of Liver Disease in the West Indies".

Friday, February 20

INSTITUTE OF NAVIGATION (at the Royal Geographical Society, 1 Kensington Gore, London, S.W.7), at 5.15 p.m.—Mr. D. McNaughton: "Meteorological Briefing Information".

INSTITUTION OF ELECTRICAL ENGINEERS, RADIO AND MEASUREMENT SECTIONS (at Savoy Place, London, W.C.2), at 5.30 p.m.—Mr. V. J. Terry and Mr. E. P. G. Wright: "The Measurement of Errors in Data Transmission for the Design of Detecting and Correcting Equipment".

UNIVERSITY OF LONDON (at Senate House, London, W.C.1), at 5.30 p.m.—Prof. K. Skovgaard (Copenhagen): "The Pattern of an Unsubsidized Agriculture".*

INSTITUTION OF MECHANICAL ENGINEERS (at 1 Birdcage Walk, Westminster, London, S.W.1), at 6 p.m.—Mr. L. E. Culver and Prof. Hugh Ford: "Experimental Study of Some Variables of the Tube Expanding Process".

SOCIETY FOR ANALYTICAL CHEMISTRY, MICROCHEMISTRY GROUP (at the School of Pharmacy, 29–30 Brunswick Square, London, W.C.1), at 6.45 p.m.—Annual General Meeting. 7 p.m.—Mr. D. F. Phillips: retiring Chairman's Address.

ASSOCIATION OF CLINICAL BIOCHEMISTS (in the Clinical Lecture Theatre, The Middlesex Hospital, Mortimer Street, London, W.1), at 7 p.m.—Prof. C. Rimington, F.R.S.: "Porphyria".

ROYAL INSTITUTION (at 21 Albemarle Street, London, W.1), at 9 p.m.—Mr. B. C. Browne: "The Earth's Gravitational Field".

APPOINTMENTS VACANT

APPLICATIONS are invited for the following appointments on or before the dates mentioned:

RESEARCH MANAGER (with an honours degree in physics or equivalent, wide research and development experience, and the ability to direct a large team of scientists) AT THE RESEARCH AND DEVELOPMENT LABORATORIES, Windscale, to direct teams engaged on research and development work for Calder Hall and for advanced designs of gas-cooled reactors—Chief Recruitment Officer, United Kingdom Atomic Energy Authority, Industrial Group Headquarters, Risley, Warrington, Lancashire, quoting Ref. 2911/J.15 (February 23).

ASSISTANT LECTURER (with experience in experimental physics, aeronomy or astronomy) IN APPLIED MATHEMATICS (GEOPHYSICAL)—The Secretary, The Queen's University, Belfast (February 25).

SCIENTIFIC OFFICER (with a first- or second-class honours degree in physics, chemistry or engineering) at the Fire Research Station (D.S.I.R.), Boreham Wood, Herts, for work on the growth and spread of fire and associated combustion and fluid flow problems—The Ministry of Labour and National Service, Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A.312/8A (February 27).

ASSISTANT EXPERIMENTAL OFFICER, for work with an electron microscope in the Plant Pathology Department—The Secretary, Rothamsted Experimental Station, Harpenden, Herts (February 28).

ASSISTANT EXPERIMENTAL OFFICER (male) at Dunholme Field Station, Lincoln, to work on sugar beet pests—The Secretary, Rothamsted Experimental Station, Harpenden, Herts (February 28).

ASSISTANT (science graduate, preferably with qualifications in physiology or biochemistry, or both) IN CLINICAL CHEMISTRY—The Secretary, The University, Aberdeen (February 28).

CHAIR OF ZOOLOGY AND COMPARATIVE ANATOMY—The Registrar, Trinity College, Dublin (February 28).

CHEMIST (male, with a degree in chemistry or equivalent qualification, and preferably experience in analysis) IN THE PLANT PROTECTIVE CHEMISTRY SECTION, to assist in studies of insecticides and fungicides on fruit plants—The Secretary, East Malling Research Station, near Maidstone, Kent (February 28).

DEMONSTRATORS IN THE DEPARTMENT OF PHYSICS—The Registrar, King's College (University of Durham), Newcastle-upon-Tyne (February 28).

IMPERIAL CHEMICAL INDUSTRIES RESEARCH FELLOWS IN CHEMISTRY, ENGINEERING or PHYSICS—The Registrar, Trinity College, Dublin (February 28).

LECTURER IN APPLIED MATHEMATICS (DIGITAL COMPUTING)—The Secretary, The Queen's University, Belfast (February 28).

LECTURER IN MATHEMATICS, and a LECTURER IN PHYSICS at Kumasi College of Technology—The Council for Overseas Colleges, 12 Lincoln's Inn Fields, London, W.C.2 (February 28).

HEAD (with a good honours degree in chemistry or a related science, with at least a registrable qualification in pharmacy, and preferably teaching or additional practical experience in some branch of pharmacy) OF THE NEW ZEALAND SCHOOL OF PHARMACY, Central Technical College, Petone—The High Commissioner for New Zealand, 415 Strand, London, W.C.2, quoting Ref. B.11/8/5 and mentioning *Nature* (March 1).

READER IN APPLIED MATHEMATICS OR IN MATHEMATICAL STATISTICS—The Clerk to the Governors, Chelsea College of Science and Technology, Manresa Road, London, S.W.3 (March 2).

LECTURER IN PURE MATHEMATICS, and a LECTURER IN APPLIED MATHEMATICS—The Secretary, The University, 38 North Bailey, Durham (March 4).

LECTURER (with special interests in one or more of the following: climatology, geomorphology, soil science) IN GEOGRAPHY—The Secretary, The University, 38 North Bailey, Durham (March 4).

IMPERIAL CHEMICAL INDUSTRIES RESEARCH FELLOWS IN BIOCHEMISTRY, CHEMISTRY, ENGINEERING and PHYSICS—The Secretary and Registrar, The University, Southampton (March 7).

LECTURER or ASSISTANT LECTURER IN APPLIED MATHEMATICS—The Registrar, The University, Hull (March 7).

LECTURERS or ASSISTANT LECTURERS IN GEOGRAPHY at the University of Malaya—The Secretary, Inter-University Council for Higher Education Overseas, 29 Woburn Square, London, W.C.1 (March 15).

RESEARCH FELLOW IN ORGANIC CHEMISTRY, for work on natural products under the direction of Prof. R. A. Raphael—The Secretary of University Court, The University, Glasgow, W.2 (March 16).

RESEARCH FELLOWS (2) IN THE DEPARTMENT OF NUCLEAR PHYSICS, Research School of Physical Sciences, Australian National University, to work either in the field of nuclear spectroscopy or on photonuclear problems—The Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (Australia, March 16).

ASSISTANT LECTURER IN MATHEMATICS—The Registrar, University College of Wales, Aberystwyth (March 19).

VETERINARY RESEARCH OFFICER or SCIENTIFIC OFFICER (with a degree in science, agricultural science or veterinary science, with postgraduate experience in entomology, preferably with reference to ecto-parasitology) at Wallaceville Animal Research Station, New Zealand, to specialize in ecto-parasitology research work of farm animals—The High Commissioner for New Zealand, 415 Strand, London, W.C.2, quoting Ref. No. B.11/2/14 and mentioning *Nature* (March 20).

LECTURERS (2) (with interests in inorganic or physical chemistry) IN CHEMISTRY at the University College of the West Indies—The Secretary, Inter-University Council for Higher Education Overseas, 29 Woburn Square, London, W.C.1 (March 21).

ASSISTANT LECTURER (with special qualifications in petrology) IN GEOLOGY—The Secretary, The Queen's University, Belfast (March 31).

IMPERIAL CHEMICAL INDUSTRIES RESEARCH FELLOWS IN CHEMISTRY OR PHYSICS—The Registrar, The University, Hull (March 31).

PROFESSOR OF GEOLOGY AND MINERALOGY at the University of Queensland, Australia—The Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1, or The Registrar, University of Queensland, Brisbane, Queensland, Australia (March 31).

RESEARCH STUDENT (with a good honours degree in zoology, or good prospects of obtaining such) IN THE DEPARTMENT OF ZOOLOGY, for work in river ecology—The Secretary, The University, Exeter (April 4).

LECTURERS (2) IN BOTANY—The Secretary, The Queen's University, Belfast (April 10).

FOREST UTILIZATION OFFICER (with an honours degree in forestry, physics or biology, able to initiate forest products research work, and preferably postgraduate experience in research and timber utilization) in Northern Rhodesia, for research work covering a wide range of forest products but primarily to improve utilization of *Brachystegia* timbers in underground conditions in the copper mines—The Director of Recruitment, Colonial Office, London, S.W.1, quoting BCD.61/3/02.

JUNIOR AND SENIOR FELLOWS (with at least 2 or 3 years postgraduate experience), for research in Chemistry, Physics, Mathematical Physics, Metallurgy, Chemical Engineering, Biochemistry and Food Technology—The Graduate Recruitment Officer (1344/34), U.K.A.E.A., Atomic Energy Research Establishment, Harwell, Didcot, Berks.

LABORATORY TECHNICIAN (male, with experience in rock sectioning, etc., photography and general laboratory maintenance)—The Secretary, The University, Exeter.

LIBRARIAN (woman, preferably with a medical or scientific background), for small medical and scientific library—Ciba Foundation, 41 Portland Place, London, W.1.

PHYSICIST (with a good honours degree) in the Middlesex Hospital Medical School Physics Department, for duties concerned mainly with radiotherapy physics—The Secretary, Barnato Joel Laboratories, Middlesex Hospital, London, W.1.

READER IN MECHANICAL ENGINEERING, and a READER IN ELECTRICAL ENGINEERING—The Registrar, Bradford Institute of Technology, Bradford 7.

RESEARCH ASSISTANT (honours graduate in botany, agricultural botany or agriculture (crop husbandry)) IN POTATO AGRONOMY in the Department of Agriculture—The Secretary, School of Agriculture (University of Nottingham), Sutton Bonnington, Loughborough, Leics.

SENIOR LECTURER (with a high qualification in chemistry, together with experience of chemical plant, or a qualification in chemical engineering and appropriate experience) IN CHEMICAL TECHNOLOGY, and a SENIOR LECTURER (with a high academic qualification together with research experience) IN CHEMISTRY—The Principal, Welsh College of Advanced Technology, Cathays Park, Cardiff.

REPORTS and other PUBLICATIONS

(not included in the monthly Books Supplement)

Great Britain and Ireland

Ministry of Labour and National Service. Annual Report of the Chief Inspector of Factories on Industrial Health for the year 1957. Pp. 50. (Cmnd. 553.) (London: H.M. Stationery Office, 1958.) 3*s.* net. [1612

European Brewery Convention. Report of the Barley Committee, Trials 1957. Pp. 138. (London: Institute of Brewing, 1958.) [1612

Proceedings of the University of Durham Philosophical Society. Vol. 13, Series A (Science). No. 6: The Age and Origin of the Hemiptera with special reference to the Sub-order Homoptera. Part 2: The Assessment, Integration, and Use of the Evidence from Fossil and Modern Homoptera in Phylogenetic Deduction. By G. Heslop-Harrison. Pp. 41–53. No. 7: Stress Relaxation in False-Bodied Suspensions. By R. Roscoe. Pp. 54–58. No. 8: On the Origin and Function of the Pupal Stadia in Holometanolous Insecta. By G. Heslop-Harrison. Pp. 59–79. No. 9: Botanical Investigations in the Isles of Lewis, Harris and Great Bernera (v.–c.110) and in the Isle of Rhum (v.–c. 104) in 1957. By J. W. Heslop-Harrison. Pp. 80–88. Vol. 1, Series B (Arts). No. 3: Types and Tokens in Language. By Barbara M. H. Strang. Pp. 17–25. (Durham: University of Durham Philosophical Society, 1958.) [1612

Stewarts and Lloyds, Ltd. Leo: a Computer in the Service of the Steel Industry. Pp. 20. Department of Research and Technical Development. Pp. 24. (Corby: Stewart and Lloyds, Ltd., 1958.) [1612

National Institute of Industrial Psychology. Report No. 13: Comments on the Job: Views of Employees in Six Companies. By Isabel Blain. Pp. iv+20. (London: National Institute of Industrial Psychology, 1958.) [1612

British Rayon Research Association. Eleventh Annual Report, October 1958. Report of the Directors of Research for 1957–1958. Pp. 30. (Manchester: British Rayon Research Association, 1958.) [1612

Ciba (A.R.L.) Limited. Technical Notes, No. 191 (November 1958): Manufacture of 'Weyroc' Chipboard. Pp. 10. (Duxford: Ciba (A.R.L.), Ltd., 1958.) [1612

The Registrar General's Statistical Review of England and Wales for the year 1957. Part 1: Tables, Medical. Pp. x+373. (London: H.M. Stationery Office, 1958.) 20*s.* net. [1612

Department of Scientific and Industrial Research. Graduates in British Industry. (The main findings of a Study by P.E.P.) Pp. iv+28. (London: Department of Scientific and Industrial Research, 1958.) [1612

Other Countries

Somaliland Protectorate. Annual Report of the Geological Survey Department for period April 1957—March 1958. Pp. ii+18. (Hargeisa, Somaliland: Geological Survey; London: Crown Agents for Overseas Governments and Administrations, 1958.) 2*s.* [1612

University of California Publications in Botany. Vol. 30, No. 1: Umbelliferae of Japan. By Minosuke Hiroe and Lincoln Constance. Pp. 1–144 (75 figures). (Berkeley and Los Angeles: University of California Press, 1958.) 2.75 dollars. [1612

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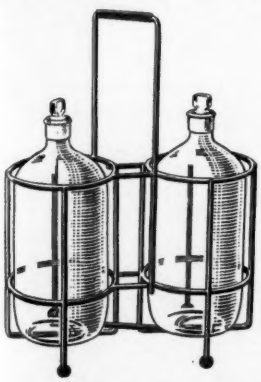

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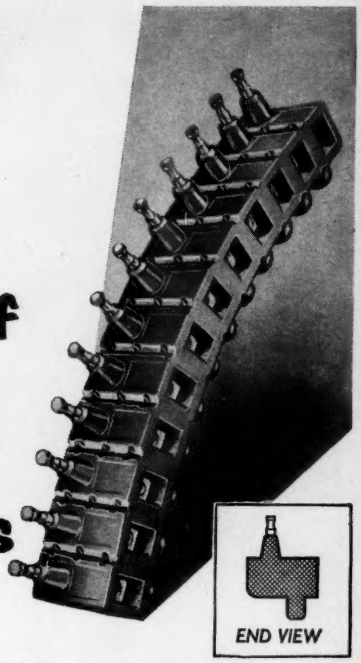

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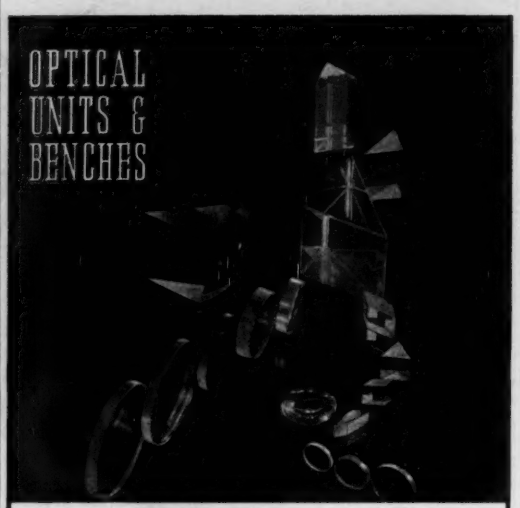

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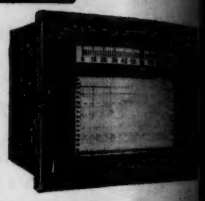

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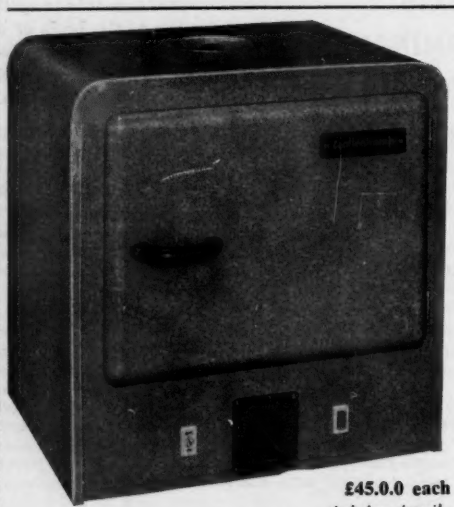

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